XXX. *Report of further Observations upon the Tidal Streams of the North Sea and English Channel, with Remarks upon the Laws by which those Streams appear to be governed. By Captain* F. W. Beechey, *R.N., F.R.S. Communicated to Sir* Francis Beaufort, *K.C.B., Hydrographer, and presented to the Royal Society by* G. B. Airy, *Esq., F.R.S., and Astronomer Royal, &c.*

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Sir, London, March 11th, 1851.

In pursuance of directions from the Lords Commissioners of the Admiralty that I should make further inquiry into the phenomena of the tidal streams of the Channel, I commenced a systematic investigation of the whole feature of tidal-streams throughout the strait which separates England from the Continent, and I have now the satisfaction to lay before you for their Lordships' information the result of these labours.

In order to prosecute this inquiry with as much advantage and as little delay as possible, I have combined with the information furnished by the vessel appropriated to this service as many observations from various authentic sources as were recommended by the known reputation of their authors.

Authorities consulted.

These consisted of various observations upon the streams of the English Channel and the North Sea by Captain Martin White, R.N., Captain Washington, R.N., Captain Hewitt, R.N., and Captain Bullock, R.N. Also by Monsieur Monnier, M. Beautems Beaupres, and by the Engineurs Hydrographiques, published in the 'Pilote Française.' To these have been added some by Mr. Græme Spence about the Scilly Islands, and a few by Captain Anderson, as given in the Philosophical Transactions; numerous observations along the shore by the Coast Guard, and a series of observations kept on board the light-vessels by order of the Trinity Board, which are particularly valuable as being made simultaneously, and, like those of Captain Washington, continued throughout several days at each station.

Method pursued in making the observations.

The method pursued in making the observations, was to anchor the vessel at each of the stations* for twelve hours and upwards, and to observe the direction of the tide, ebb and flood, every half-hour. The rate of the stream, in addition to the usual method by the common log, was detected by current logs, constructed for the purpose by Mr. Massey, and which registered feet; and that it might be ascertained whether the stream was confined to the surface or extended to the depth of a vessel's hull

* See Chart of the Stations, Plate XXXII.

in the water, another of these logs was occasionally sunk 12 feet, and registered simultaneously with the one which was 2 feet beneath the surface.

Method of making the observations.

The time of slack water, as well as the times of the cessation and commencement of the stream, were noted, as closely as such observations are capable of being made; and to render the times more certain, I have taken the mean interval between the time of the cessation of one stream and the time of the commencement of the next. The times of high water at Dover have been taken from the Admiralty Tide Tables, which were tested by observations made at Dover during some portion of the observations in the Channel, and the agreement being found sufficiently near to render a special register unnecessary, it was discontinued.

All the times of observation being referred to the *meridian of Dover*, and compared with corresponding times of high and low water at that place, tables of differences were obtained which gave *the interval between the time of slack water at each station, and the time of high water on the shore at Dover*, and also the direction and rate of the stream at each hour of the tide before and after the same standard. By this method of comparison observations made at various periods, and even in different years, were brought as nearly as possible to a simultaneous record.

To exhibit these results tables were drawn out, and twelve charts were constructed, showing the position of the stations and the direction of the stream at each hour of the tide at those places respectively, in order that the eye might at once detect the movement of the stream throughout both channels at any instant of time*.

In these charts the direction of the stream is indicated by arrows, which are connected by curved lines empirically drawn through them; these lines are continuous when the water is flowing towards Dover, and broken when running in the reverse direction. Lastly, all those tides which have a rotatory motion are indicated by spirals barbed in the direction in which they revolve.

Results.

All the observations having been subjected to this arrangement, some highly important results were obtained. Instead of these channels having, as has been hitherto supposed, a stream which turns progressively later as the tide advances up the strait, these observations have shown that the progressive changes of stream cease at a certain point near the mouth of the Channel, and that beyond that spot there is a tide peculiar to the Channel, and quite distinct from that of the seas on either side of it; so that there may be said to be two distinct streams on each side of the Strait of Dover,—the stream of the Ocean or outer stream, and the stream of the Channel, or that which is contained between the oceanic stream and the Strait of Dover. These streams are always running in contrary directions, and in the North Sea meet between the Texel and the estuary of Lynn; and in the English Channel between the Start and the Gulf of St. Malo.

Oceanic and Channel streams.

Mixed tides.

In the localities where these streams meet, the tide is ever varying its direction according as the strength of one stream prevails over that of the other; giving to the

* Eight of these charts only have been published.

water a rotatory motion, and scarcely admitting of any interval of slack water; whilst in the space between these rotatory tides and the point of meeting of the tides in the Strait of Dover, the stream is free from all rotatory motion, and sets steadily throughout the tide in a direction *towards* Dover, while the water is *rising there* and *away* from it while it is *falling at* that place.

Rotatory streams. True Channel stream.

I have designated the last-mentioned the "*true channel stream*," and its extent is, as nearly as it can be measured, 180 miles in either direction from the point of union of the tides in the Strait of Dover to the region of rotatory tides off Lynn, and off the Start and St. Malo.

Extent of the Channel stream.

As the true Channel streams are always running in opposite courses, there is necessarily a point where they meet and separate; and this occurs in the Strait of Dover. But *in this strait*, the stream, although it first obeys one tide and then the other, does not slack with the Channel streams, but is found to be still running at high and low water on the shore, at which times those streams are at rest, so that the Strait of Dover never has slack water throughout its whole extent at any time. I have in consequence called this an *intermediate* tide.

Meet in the Strait of Dover.

Intermediate tide.

The limits of neither of these streams appear to be stationary, but *range to and fro as the tide rises and falls at Dover*, travelling to the *eastward* on *both* tides, and at high and low water suddenly shifting sixty miles to the westward to recommence their easterly courses with the next tide; and although so far apart, they possess the remarkable peculiarity of shifting together; so that the Channel streams preserve, as nearly as possible, the same relative dimensions.

Place of meeting of the tides changes with advance of the tide.

In the Strait of Dover this line of meeting and of separation oscillates between Beachy Head and the North Foreland, a distance of about sixty miles. When the water on the shore at Dover begins *to fall*, a *separation* of the Channel streams begins off Beachy Head. As the fall continues, this line creeps *to the eastward*. At two hours after high water it has reached Hastings; at three hours Rye; and thus it travels on until at low water, by the shore, it has arrived nearly at the North Foreland on one side of the strait, and at Dunkirk on the other. At this time the *Channel streams* on both sides slack, but in that portion which I call *the intermediate stream* in the Strait of Dover the water is still running to the westward; and when the new *Channel* streams make as the water rises on the shore, this *intermediate* portion is found to unite with, or to oppose one or the other of these streams, according as it was before the reverse; so that, as before mentioned, the line of meeting at low water appears off Beachy Head to recommence its easterly course. This *intermediate* stream forms a remarkable feature in the tidal system of the Channel; it is well established, as the line of meeting and of separation occupies a very limited space, and it seems to be entirely due to the contracted form of the Channel in this immediate locality, preventing the free escape of the water.

Peculiarity of the stream in Dover Strait.

Captain Bullock, in order to test the point of separation, anchored two vessels a mile apart between Beachy Head and Dungeness, and found both vessels at the same

moment to ride with their heads in opposite directions, in obedience to the streams which were then running opposite ways.

Channel stream.

The *Channel stream*, which I have described as running between the intermediate stream and the rotatory or mixed streams at the outer extremities of the Channel, pursues a steady course along the main trunk of the strait, slacking only towards high and low water at Dover, when it is preparing to invert its course; and contrary to the generally received opinion of *a progressive slack water* in a strait having *a progressive establishment*, this stream has the peculiarity of slacking throughout its whole extent at *nearly the same time*, and this time, as was anticipated in my former paper, corresponds nearly with the time of high and low water on the shore at Dover, the site of the combined wave and of the *virtual head of the tide*.

Stream slacks at nearly the same time throughout.

Such is a general description of the phenomena of the streams of the English Channel and the North Sea; and I shall now endeavour to describe more in detail the several peculiarities of these features, and to remove various erroneous impressions which at present exist as to the rotatory motion of our tides, the direction in which the streams turn, and also as to the time of the stream attaining its maximum rate, &c., and then to lay before you such data as it appears to me will help to explain the cause of the tidal streams of these channels differing from those peculiar to ordinary tide-waves.

Simultaneous turn of the stream.

As the simultaneous turn of the stream is a point of considerable interest, I may be permitted to dwell a few minutes upon the data from which it has been derived. But I wish it to be clearly understood, that minute accuracy on such a point is scarcely possible, and could only be obtained by a long series of simultaneous observations at the extremities of the tide-wave; for the period of slack water is almost always spread over an interval of half an hour, and not unfrequently at the neaps, of an hour and upwards; and moreover winds are found to prolong the stream in the Channel according to the direction in which they blow. In estimating the time of slack water therefore from the observations, we must not expect a very close agreement*.

Time of high water at Dover, and the time of the turn of the stream compared.

It will be seen, on a very cursory inspection of the Charts which accompany this paper, that for a period of six hours after high water at Dover, and for five hours before that time, the stream maintains a steady direction from and towards Dover, so that any delay which may exist between the change of the stream and the time of high water is shown by these charts alone to be confined within very narrow limits, but a still closer agreement will be found on referring to the observations themselves*; especially if we take those which were made on board the light-vessels at a distance from the shore, which are particularly valuable from the circumstance of their being spread over intervals of several days at each station.

* The times of observed slack water at the stations marked in the Plans, as compared with the times of corresponding high waters at Dover, as shown by the tide tables, together with all other particulars relating to these observations, will be found entered in a book which accompanies this report, since deposited at the Hydrographic Office of the Admiralty.

Referring then to these observations, and taking them in the order in which the light-vessels are placed with respect to the progress of the tide-wave, we shall have the intervals between the turn of the stream at those places, and the time of high water at Dover (the standard), as follows:— Comparison continued.

At the Newarp L.V., the stream is slack twenty-two minutes before Dover.

At the Cockle L.V., the stream is slack at the same time as Dover.

At the Stanford L.V., the stream is slack nine minutes before Dover.

At two stations nearer Dover, the stream is slack twenty-four minutes after.

At the Shipwash L.V., the stream is slack twenty-four minutes after.

At the Galloper L.V., the stream is slack the same time as Dover.

At the Kentish Knock L.V., the stream is slack nine minutes after Dover.

Lastly, off the North Foreland, the stream is slack the same time as Dover.

Between these stations and the meridian of 3° 0′ E. we find the following intervals.

In the parallel of Cromer, twenty-four minutes before Dover; at the next station, southward, twenty-four minutes after; at the next, four minutes after; then, thirty-six minutes after; at the next, nineteen minutes after; at the next, three minutes after; and lastly, off the North Foreland, the same time as Dover.

In the first set of comparisons the differences are not greater than might be attributed to the ordinary irregularity of the tides; in the second we discover a progressive increase, and then the phase of the stream seems to be inverted, until at the end of the series we find the interval vanish, and the stream to turn with the high water on the shore.

To the eastward of 3° of longitude, the times of slack water get considerably later in that part of the Channel which lies between the northern limit of the Thames and the Texel, and the phase of the stream in all this portion of the North Sea appears to be inverted; the intervals also to get *longer* as the Dutch coast is approached. The occurrence of this *inversion of the phase of the stream with the inversion of the phase of the establishments on the coast of Holland, and its position occupying the site of the node of the tide in Professor* Whewell's *chart of cotidal lines*, is a coincidence which ought not to be overlooked, although I am not able to discover any connection between the phenomenon, which is evidently the cause of the unusual retardation of the stream above-mentioned, and the phenomena of the cotidal chart. Retardation of the turn of the stream towards the coast of Holland.

There seems to be very little doubt that the retardation of the stream, and the consequent inversion of phase now noticed in all this part of the Channel, is entirely owing to *the outer stream setting round the Texel*, at a time when the stream is slack in all other parts of the Channel and preparing to go round*. Cause of the retardation of the turn of the stream towards the coast of Holland.

An inspection of the Plan for one hour after high water will clearly show this to be the case; it will there be seen that the stream of the Channel is making an effort

* See Chart one hour after high water, Plate XXXIII.

to run to the northward, and on the western side of the Channel has succeeded, the North Sea (or outer) stream being in that part favourable to it; but on the *eastern* side of the Channel, the stream coming round the Texel forces its way up the Channel, and creates a temporary disturbance, which is no doubt the cause of the retardation of the turn of the stream in this vicinity.

The two consecutive charts strengthen this supposition, by exhibiting the Texel stream receding as the Channel stream gains strength.

Comparison of time of slack water in the North Sea with the time of high water at Dover.

If, then, we except such observations as are shown to be due to the disturbance from the Texel tide, we shall find that *in the whole extent of channel from Cromer to the North Foreland, there is not half an hour of retardation in the time of slack water from the time of high water at Dover, while in the establishments there is an increase of at least five hours.* That we may appreciate this very small difference of the time of slack water throughout the Channel and the time of high water at Dover, let us inquire what takes place in parts of the North Sea, which exhibit the ordinary phenomena of tides under the influence of a progressive wave, such for instance, as are comprised in the space between Kinnaird's Head and the estuary of Lynn. There is in this space an increase of tidal establishment of five hours, an amount about equal to that which exists between Lynn and Dover. By the Admiralty Tide Tables, it will be seen that in this space there are nearly five hours' retardation in the time of slack water in the offing, making at least, *hour for hour in the change of the stream with the change of establishment*; whilst in the North Sea, in the same change of establishment, there is scarcely *half an hour difference of time in the change of stream.*

Comparison of time of slack water in the English Channel with high water at Dover.

If now we take the English Channel, we shall find half-way between the Start and Alderney, that the stream *turns with the high water at Dover.* Off Portland, *nine minutes before*; off St. Albans, *three minutes before*; between the Isle of Wight and Cape Barfleur, *fifteen minutes after*; and so we run on, the differences varying from *eight minutes one way to an extreme of forty-two minutes the other**. In the Baie de la Seine, the turn of the stream is earlier in the western part than towards its eastern extremity, but the formation of the coast about Cape Barfleur will fully account for this.

In the eastern part of the Baie de la Seine a retardation occurs towards the Somme; in that direction the turn of the stream, on the south side of the Channel, *is an hour later than* on the north side opposite; the observations, however, upon that coast are not given in a manner sufficiently clear, and they were made many years ago, and compared with the establishments of ports, which might not at that time have been very accurately determined; therefore I would not dwell much upon them*.

Upon the whole, therefore, judging from the observations which have been collected, there seems to be sufficient evidence to warrant the conclusion, that, with the excep-

* The vessel now about to sail to continue this inquiry, will, it is hoped, get some observations in this quarter.—November 5. Recent observations have shown these intervals to be in excess.

tions arising from extraneous causes, which are now known, and for which an allowance can be made, the streams of the Channel turn sufficiently near to the times of high water on the shore of Dover to be considered as simultaneous, without occasioning any error that can be of the smallest consequence to shipping*.

On the rotatory motion of the stream.

I shall now pass to the next point of interest,—the supposed rotatory motion of the stream in the English Channel and the North Sea. It will be seen by the Charts, that wherever any circular motion of the water appears, it occurs between the outer extremities of the Channel tide and the stream of the oceanic or parent wave; and is clearly to be accounted for by the streams acting obliquely upon each other.

Erroneous ideas respecting this motion.

Captain MARTIN WHITE and Mr. GRÆME SPENCE, who have written upon the tides of the English Channel, were of opinion that this rotatory motion was not only applicable to the whole of the Channel, but common to the tides of all the world. Captain WHITE, in his remarks upon currents, &c., observes, at p. 35, "Tides are governed by a regular periodical reciprocation in most parts of the world, making the round of the compass almost everywhere during the twelve hours. This rotatory motion," he continues, "is perfectly symmetrical during and after a series of moderate weather, and the curves it assumes resemble the form of *spiral curves*." It was Mr. GRÆME SPENCE, however, who originated this idea of a revolving tide†. It is a singular circumstance that the observations of these officers should not have extended to parts of the Channel where the stream runs true, but have been confined to the mixed tide. Mr. GRÆME SPENCE obtained his observations in the vicinity of the Scilly Islands, where the streams of the Atlantic and of the English Channel unite; Captain WHITE's observations extended further up the Channel, but still not far enough to be clear of the effect of the Gulf of St. Malo. M. MONNIER‡, who has often been quoted as the well-known author of a pamphlet on the tides of the English Channel, derived opinions similar to those above-mentioned, from observations made about the Channel Islands also; and was confirmed in his opinions by some observations made about the same time by Captain HEWITT in the North Sea, near the Lemon and Ower sands, which, curiously enough, are on the border of the mixed tide of the

Cause of this erroneous opinion accounted for.

* In my paper upon the tidal phenomena of the Irish Sea, I particularly referred to the nearly simultaneous turn of the stream in that channel which is also under the influence of a combined wave. Since that time observations have been made at the Smalls Lighthouse, at the Kunibeg and at other light-ships; all of which have confirmed in a very satisfactory manner those remarks.

At the Smalls, for instance, situated at the entrance of the Irish Channel, and differing from Liverpool nearly five hours in its establishment, the time of slack water occurs *fourteen minutes* only before high water at Liverpool; at the Kunibeg, *twenty-one minutes before*; then the mean of the intervals in the first page of observations, between Smalls and Bardsey, gives *four minutes after Liverpool*; the mean of the next page of observations thence to Holyhead, *thirteen minutes after*; going northward, the mean of the next page, *twelve minutes after*; off the Isle of Man, *at the same time*; and in the North Channel, *twenty-four minutes after*.

So that throughout the Irish Sea, as in the Channel which separates England from the Continent, the stream slacks throughout at nearly the same time as the combined wave is matured; or as the time of high water at *the virtual head of the tide*, as already stated in my first report.

† See his observations on the tides of the Scilly Islands. ‡ Mémoire sur les Courants de la Manche.

On the rotatory motion of the stream.

North Sea, as those of Mons. Monnier were on the border of the mixed tide of the other sea. These authors have been followed by other talented men, until a common opinion was gaining ground that streams in general had a rotatory motion.

Had the observers above-mentioned made their observations anywhere between the Start and Beachy Head, or between Cromer and the North Foreland, a different result would have been obtained; for in all this space, occupying nearly 360 miles in extent, the stream runs steadily throughout both tides, scarcely changing its direction for four hours and upwards, and then only preparatory to going round to the new coming tide.

Explanation of Plan 1, Plate XL.

Upon Plan 1, Plate XL. I have given examples of the streams in question. The upper figures represent the revolving tides, exactly in the order in which the observations were made, on a direct line between the Texel and Cromer. The circular arrows show the direction in which the stream revolves, and the figures against the arrows the times before and after high water in which the streams run in those directions. The second line of revolving tides was observed in the mixed tides off the Start, and is similar to those off the Texel. The lower lines are samples of the steadiness of the stream which prevails throughout the ordinary tides of the Channel; the stations are given exactly as they occurred on a parallel of 52° 15′ N., which nearly intersects the position Professor Whewell has assigned to the node of the North Sea tide, and as they were observed in the English Channel between Portland and Beachy Head.

It was in the upper or revolving streams that the late Captain Hewitt's observations were made, and in the second row, or similar tides, that M. Monnier and Captain White made their observations; and there can no longer be any doubt that the rotatory tides are the exceptions to the general courses of the stream, and not the rule.

On the time when the stream attains its maximum rate.

The time at which the stream attains its maximum rate in the Channel is another point of interest and of importance to the seaman. In the 'Pilote Française' we find numerous observations carefully drawn out, and all giving nearly the same result, which is to place the strongest part of the stream at high and low water, and the slack water at half-tide. In 'Mémoire sur les Courants de la Manche,' before referred to, we read at p. 15, "On conclura de ce qui vient d'être dit que l'heure de la haute mer doit coincider avec celle ou le courant de flot acquiert sa plus grand vitesse..... On concevra de la même manière que le courant de jusant doit atteindre sa plus grand vitesse au moment de la basse mer.....:" and in a work of high authority published in this country, it is stated, doubtless from the authorities beforementioned, that "in mid channel the motion of the water will be flowing most rapidly up the Channel at the time of high water, and its motion upwards will cease when the water has dropped to its mean height."

This idea of M. Monnier, viz. of the strongest part of the stream occurring at high water on the shore, is part of the same error which the author before quoted had

fallen into respecting the turn of the stream in the Channel, viz. that of comparing the observations with a false standard. Taking the same observations and comparing them with the high water at Dover, the times in question all give the half-tide as the period at which the stream attains its greatest strength; and by referring to another table, in which our own observations are compared, a precisely similar result is obtained. The question is a very simple one, and rests entirely upon the truth of the observations, a specimen of which I have given in the subjoined Table for the purpose of consultation.

The time at which the stream attains its maximum rate.

Table showing the time at which the stream attains its greatest strength, and also its rate per hour at that time.

English Channel.						North Sea.					
No. of station.	Time from high water, Dover.	Rate of stream.	No. of station.	Time from high water, Dover.	Rate of stream.	No. of station.	Time from high water, Dover.	Rate of stream.	No. of station.	Time from high water, Dover.	Rate of stream.
	h m	Knots.		h m	Knots.		h m	Knots.		h m	Knots.
12	3 15	1 81	G	2 50	5 00	3	4 40	1 18	41	2 30	2 35
	2 30				4 50	4	3 00	2 07		2 10	2 35
13	3 00	2 27	H H	2 34	2 30		2 45		42	3 00	2 30
	3 30			2 00	2 30	6	2 30	2 53		2 30	2 45
14	2 15	2 05	E E		2 00		2 15		43	3 00	2 70
	2 00				2 00	8	3 00 E.	2 84		2 30	2 90
15	3 15 E.	3 80	D	3 00	3 70	10	3 00	2 25	44	3 15	2 40
16	3 15	3 14		2 40	3 70		3 00				
	3 00		O	2 45	4 50	12	3 30	1 65	45	3 00	2 60
17	2 30	3 30		3 50	3 60		3 30			3 00	2 21
	3 00	2 75	48	3 00	3 2	13	3 30	1 60	46	3 00	1 85
18	2 15	2 20		3 40	3 0		4 00			2 00	2 00
	3 00	1 60	79	3 00	3 15	14	3 00	1 37	100	2 35	2 60
19	2 45	2 75		3 00	2 90		2 45			3 00	2 60
	3 00	2 00	47	3 00	3 4	15	3 30	1 54	101	2 45	2 00
20	2 30	2 25		2 15	3 2		3 45				
	3 30	1 80	46	2 10	3 6	17	2 45 E.	2 91	102	3 00	1 60
A A	3 20 E.	1 30		3 30	3 3	18	3 30	2 44		1 45	1 85
A	3 20	1 20	49	2 10	3 3		3 30		102A.	3 00	
B	2 10	2 00		3 30	3 1	19	2 45 E.	2 33		2 30	
	3 20	2 50	58	In the Baie de	3 2	39	2 30	2 25	103	2 45	1 70
C	2 20	3 80		la Seine.		45	4 00	2 10		1 35	2 15
	3 00	3 80	77	2 30	3 6		2 30		104	3 00	2 60
D	2 45	3 86		3 00	3 15	37	4 00	3 00		3 15	3 00
	3 15	4 33	61	2 5	3 2		2 45	2 40	107	3 30	1 40
E	2 40	2 80		3 5	3 0	38	2 40	2 50		3 20	3 00
	3 10	2 80	75	3 00	3 5		2 45	2 18			
E*a*	2 30	2 80		2 30	2 9	39	2 30	2 50			
	3 30	2 80	76	2 50	3 6		2 45	2 35			
				3 00	3 20	40	3 00	2 40			
							2 45	1 64			

In the 2nd, 5th, 8th and 11th columns of this Table are given the times before and after high water at Dover at which the stream attains its greatest strength, which is clearly seen to be about the time of *half-tide*, Dover, and not, as supposed, at high and low water on the shore.

Direction in which the stream turns.

The *direction in which the stream turns* will next engage our attention. This is a question more curious than useful to the navigator; it is nevertheless one of interest, and I have given it my attention.

Upon Plate XXXII., I have shown, by curved arrows, the direction in which the streams in all parts of the Channel pass through their various rhombs, and I cannot discover that there is any general rule with respect to *particular sides of the Channel.* On the contrary, the direction appears to be wholly dependent either upon the course of that stream which commences first or continues the longest, or upon that which becomes the most powerful, and which, acting obliquely upon the weaker stream, compels it to partake of its own direction. A good example of this may be seen in the chart of the streams at three hours after high water (Plate XXXV.), where the incoming Ocean stream off the Lemon and Ower is dividing the Channel stream and causing all the tides to the eastward of that spot to turn *with the sun,* and those to the westward of it in a *contrary direction.*

On a supposed tide and half-tide.

I have now only to mention a popular error which still exists with reference to the streams of our channels, viz. a belief in a "*tide and half-tide*;" by which it is understood that the stream runs half a tide longer near the centre of the Channel than it does near the coast. So general an opinion requires substantial proof to invalidate it, and I must refer once more to the diagrams which accompany this report. It will be seen there that in no part of either channel does the change of stream in the centre differ even an hour from the change of stream as near the land as a vessel would be safe in navigating, except in that part of the North Sea which is affected by the tide sweeping round the Texel; and then, at the most, it amounts only to a quarter-tide. It is not difficult to discover that this error has arisen from the confusion of high water on the shore with the time of slack water in the offing.

I have now described the principal features of the tidal streams of this strait, and it is evident from the observations which have been collected that the laws by which the streams of these channels are governed, differ materially from those which regulate the streams of ordinary tides.

It will be interesting to see in what this consists, and to endeavour to account for the cause.

Peculiarity of the wave of the English Channel and North Sea.

Under ordinary circumstances, such as those which attend the passage of a *single tide*-wave up an estuary or deep gulf, or even along an open coast, we find *a progressive turn of the stream to accompany a progressive increase of establishment.* But in the channels under discussion the stream is found to turn *nearly simultaneously throughout the strait,* wholly regardless of the *order of its establishments,* and to reverse *with the time at which a wave peculiar to such channels is matured.*

This wave, which exercises so singular an influence over the streams of these Channels, is occasioned by one portion of the oceanic tide-wave of the Atlantic passing round the north end of the British Islands, while the other finds its way up the English Channel and meets it in the Strait of Dover. In consequence of this meeting or opposition, the character of the wave is changed; its dimensions become

diminished just one half in extent, its rate of travelling is reduced a like quantity, and its streams are almost always in opposition to those of the outer or parent wave.

Formation of a combined wave in the Strait of Dover.

Plans 3 and 4 exhibit the forms of this wave at full and change, as they appear at the hours respectively marked against them at the side of the Plan. They are constructed principally from the establishments and ranges of tide published in the Philosophical Transactions, 1836, Part II., by drawing a line through the fairway of the Channel, and setting off upon it the times of high water and the ranges of tide as they would exist at the stations selected for this purpose.

In these Plans we can distinctly trace the formation of a combined wave at Dover. In Plan 4, for instance, at V hours, the crests of two waves are seen to be formed a little beyond the Deadman on one side and at the Spurn Point on the other, and the foot of the wave or hollow which they create is resting at Dover. Following the progress of these two crests down the page, we find them gradually approaching each other and wearing out the depression in advance of them, until between VIII. and IX. o'clock the hollow has vanished; at X. o'clock there is a decided convexity of surface, which gradually increases until at XI. o'clock, Plan 3, the crest has attained its zenith: the combined wave is perfected, and it is high water at Dover.

If now we follow the wave down the same page, Plan 3, as the tide falls, we find the crest to become more oblate, and finally, to be obliterated without there being any material progress of the wave in either direction. In fact, the wave on this section appears to descend nearly perpendicularly, and the progress of the derivative waves to be so far destroyed that we can scarcely trace any indication of their advance. On the contrary, we see a new wave on each side preparing to roll up the Channel to renew the wave thus clearly common to both. So far then we perceive, from these data, that the wave in the Strait of Dover is due to the combined action of two waves derived from the parent or Atlantic wave, and which advance from opposite quarters. These waves, it may be seen, are materially different in their dimensions and rate of travelling from those of the oceanic wave from which they are derived. The dotted line drawn through the crests of the wave upon the Plan 3, will sufficiently discover the material change it undergoes on approaching the channel in which the branch wave exists.

The same result, nearly, as regards the formation of the combined wave, is arrived at if we take a mean between the sections of the wave as it would appear from the ranges and establishments along the coasts of England and of France and Belgium. In this mean section, however, we trace the formation of a combined wave at IX. o'clock off Selseabill, and can detect a progressive advance of a small wave thence to the eastward, making high water along the Dutch coast in the inverse order of the high water resulting from the wave upon the opposite side of the channel, and then merging into the wave preparing to renew the order of the tides in the North Sea*.

* This merging of the waves into each other may possibly be the cause of the whole rise of the tide at the Texel occurring in the first half of tide, as stated in "Ariel," Remarks upon the Tides of the Texel, published at Amsterdam.

This wave is not, however, of sufficient magnitude to affect *the streams* which traverse its surface, which seem to be under the entire control of the combined wave. The inverse order of the establishments upon the coast of Belgium and of Holland is a point of considerable interest, and I greatly regret that the season has been so unfavourable that no observations have been made which throw any additional light upon the subject.

If we place the mean water-level of the middle sections of the wave together, we shall form the figures traced in Plan 2, Plate XLI., and shall be struck with the very small limits off Harwich through which the large wave at Dover is transmitted; this contracted portion of the sketch is nearly in the situation in which Professor Whewell has drawn the node of the North Sea tides.

Powerful influence of the combined wave over the streams of the Channel.

The influence of the combined wave over the tidal phenomena of the channels on both sides of the Strait of Dover is very remarkable. The streams of both it will be seen reverse together as the wave is matured; they extend to the same distance from the apex of the wave, where they are met by rotatory streams; in short, the whole tidal feature of one-half of the strait bears so close a resemblance to that of the other as to leave no doubt of their being both due to a common impulse. For instance, it may be seen in the Plans which accompany this report, that in the North Sea the streams of the oceanic and Channel wave meet off the estuary of Lynn, as they do off the estuary of St. Malo in the English Channel, at the same hours and at the same distances nearly from the head of the combined wave; that there is an increased rise of the tide at Lynn as in the Gulf of St. Malo, although not to the same extent, owing perhaps to a different conformation of coast, but sufficiently large to establish the similitude, being in both cases nearly double that of the offing rise; that in these localities, on both sides, the streams are all of a rotatory character, and that from the meeting of the streams off Lynn to the meeting of the streams off Dover, there is, as in the English Channel, from the meeting of the streams off St. Malo, to the meeting of the aforesaid streams off Dover, a stream which flows steadily on both sides towards Dover, whilst the water is *rising* at that place and sets *away from it*, whilst the water is *falling* there; each portion having the remarkable peculiarity of reversing its stream throughout nearly simultaneously with the time at which the combined wave is matured.

Streams of the Irish Channel under a similar influence.

I may here observe, that in this respect the Irish Channel is precisely under the same circumstances as the English Channel and North Sea. The tide-wave enters that sea in like manner by opposite routes, and forms one vast wave, having all the peculiarities of a combined wave. On each side of the apex of this wave the streams reverse throughout at nearly the same time; that time corresponding with the time at which the combined wave is perfected, as occurs with the streams in the English Channel.

In the Irish Channel the streams are even more regular than those of the North Sea and English Channel, and suffer less disturbance from the ocean or offing streams. It is true that in the Irish Sea there is no intermediate stream where the tides meet,

but, on the contrary, a large tract of still water which the streams scarcely ever disturb, but this arises from the different conformation of the inner part of the strait. The Irish Sea, for instance, may be said to be contracted at its entrances, and to expand into a large inland sea in its centre, whereas the other channel has wide entrances and a very contracted centre. They are, however, both canals in which the waves from two tidal seas enter at opposite ends and meet in the centre, where they form a combined wave, and hence they have the property of reversing their streams simultaneously.

Tidal phenomena of the Irish Sea and of the English Channel compared.

There cannot therefore be any doubt that the waves which are formed in the centre of these straits exert a powerful influence over the course of the waters on both sides of them, and in fact that they both govern their movements and regulate the limits of their streams.

It was the consideration of this influence that determined me to refer all the movements of the streams of these Channels to the time when the combined wave was matured. In the Irish Sea I adopted Liverpool as the standard*, and as Dover was situated so near to the apex of the wave in the English Channel, and had tables of its tides already printed and in general circulation, I adopted the time of high water at that place as a standard to which all the observations there should be referred.

I shall now compare the general inclination or slope of the surfaces of the combined wave on both sides with the direction of the streams passing along the Channel at the moment, for the purpose of showing the mechanical action of the water, and of tracing the intimate connection that exists between these slopes and the simultaneous turn of the stream.

Comparison of the inclination of the surface of the wave with the direction of the stream along it.

If we direct our view to the inclination of the surfaces of these waves, Plans 3 and 4, Plates XLII. XLIII., we shall see that the directions in which the streams run do not always correspond with the *existing* slopes of the surfaces, as they might be supposed to do from the known law of gravitation, but that during the last half of the tide they are to be traced to the effect of *a previous* and contrary depression. The maximum rate of the stream may be seen to occur when the surface has its smallest depression†, and that there is no stream at all at the moment of the greatest elevation and depression. It will be seen that the rate of the stream depends upon the amount and continuance of the inclination; and also that a stream, when once produced, will continue its progress for a length of time, although the inclination that produced it may have been reversed by the passage or descent of the crest of the wave. Consequently from the time of the passage of the wave, or the reversal of the inclination of its surface, until the stream finally ceases to flow, the water will be seen to run up an inclined plane, and will continue to do so for nearly as

* See my paper in Philosophical Transactions, Part I. 1848.

† The maximum rate of the stream is shown in the Table at page 711 to occur at half-tide, at which time the wave is seen to have the smallest depression.

long an interval before it be brought to rest as it did to acquire its momentum, the relative inclinations at the beginning and end being about the same.

The reversal of the stream throughout the strait at the same time will not therefore be a matter of surprise, as it will be seen to be only the effect of gravitation due to *the general slope* of the surface. That it is the *general slope* of the surface of the combined wave that occasions the stream throughout these channels, is even more manifest in the North Sea than in the English Channel, from the fact of the stream there pursuing a steady course between two shores, of which the order of their tidal establishments is inverted without reference to either.

Cause of the stream explained.

If it be required to trace the streams of the Channel through their gradations, it may be done on Plan 3, thus: at XI. o'clock, it is high water at Dover, the wave has consequently attained its zenith, and the depressions of the surfaces on either side are at their maximum. There is now no stream, because the momentum acquired during a former depression has only now ceased, notwithstanding the increasing obstruction for two hours which has been presented by the reversed inclination of the wave. The water at Dover now falls, the stream begins, and as the depression of the surface continues, the stream gradually acquires strength until about half-tide, when the depression is at its minimum and the strength of the stream at its maximum: after this the inclination of the surface is unfavourable to a continuation of the stream. From this time, therefore, the rate of the stream begins to diminish, because the reversed inclination is progressively becoming more adverse to its progress, and at low water at Dover, after having run up an elevation for two hours, its effort is exhausted and there is slack water throughout the wave, as at first*.

Conclusion.

In conclusion, I trust it will appear to their Lordships, that the means which they have been pleased to place at my disposal have been advantageously employed; and I venture to express a hope, that whilst science will be benefited by the inquiry, the navigation of our channels will be so far improved that the seaman will in future find his course through these moving waters rendered simple and plain. Hitherto the numerous and perplexing references which he has been compelled to make to establishments of ports, with some of which he was not even furnished, and which, under any circumstances, rendered a calculation necessary, have in too many instances, it is feared, caused the set of the tides to be wholly disregarded, or what is worse, misapplied, the consequences of which, it is now seen, are very likely to have been attended with disastrous results. For instance, the meeting of the streams off the Casquets and the Start in the English Channel, and the direction there given to the water at a particular time of the tide, will fully account for the numerous wrecks about the Channel Islands; whilst near the Strait of Dover an unexpected set of the stream directly down upon the Somme, and in a part of the Channel where from its narrowness a true stream might be expected, is evi-

Beneficial results of this inquiry to the seaman.

* In my report upon the streams of the Irish Sea, Philosophical Transactions, Part I. 1848, at figures A and B the effect is there shown to be precisely the same.

dence of the danger of approaching this part of the Channel if ignorant of the set of the stream; and most singularly this unsuspected evil occurs exactly in the spot where those disastrous wrecks of the Conqueror and Reliance took place, and where the Curaçoa, one of Her Majesty's frigates, so narrowly escaped a similar fate.

Henceforward a simple reference to a Dover tide table will enable the mariner to determine in which direction his vessel is being carried, assured that whilst the water is rising at Dover he will have a fair stream from the Lemon and Ower to the North Foreland in one channel, and from Alderney to Beachy Head in the other, and *vice versâ*; whilst the times and places of the meeting of the streams will be apparent upon the Plan, so that it is hoped, when the contents of the present paper are sufficiently known and circulated, they will be the means of diminishing the number of those losses of both life and property with which the annals of Lloyd's abound, and of advancing our knowledge of the tides by the practical illustration of the phenomena of the tidal streams of straits under the influence of a combined wave.

In closing this report, I particularly wish to observe that my thanks are due to the officers whose names have been mentioned as having contributed to this inquiry, and especially to the Trinity House and Captain Bax, to whose exertions in training the light-vessel keepers the observations made by them owe their value; and to Captains Washington and Bullock and the officers, who have been engaged in both making the observations and drawing the plans.

To you, Sir, I am indebted for the unremitted assistance you have rendered this cause by the exercise of a zeal which is ever forward in promoting whatever tends to the improvement of navigation or to the advancement of science.

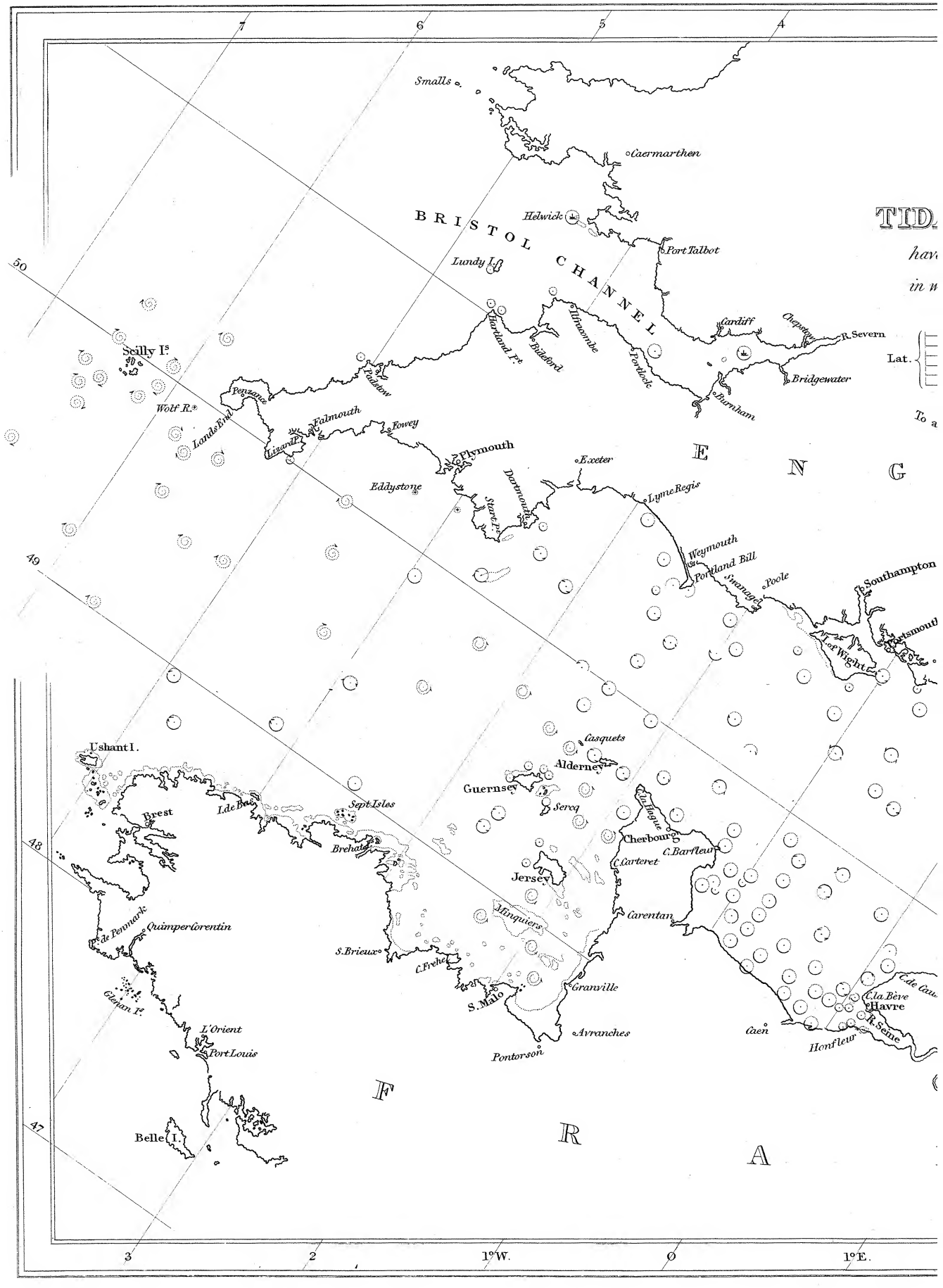
I am, Sir, your humble Servant,

F. W. Beechey, Captain R.N.

To Rear-Admiral Sir Francis Beaufort, K.C.B.,
&c. &c. &c.,
Admiralty.

Note.—Since this report was forwarded, observations have been made between the Spurn and Helgoland, and it appears that in all that part of the sea lying between the rotatory streams off the Texel and Helgoland, or rather between 2°·30 E. and 7°·30 E., the stream *turns nearly simultaneously* with the time of high water at Helgoland and at Dover, the establishments of those places being nearly the same. We may therefore look for a combined wave at the mouth of the Elbe, and for a succession of rotatory streams extending to a considerable distance in a north-easterly direction from Lynn. A few observations have been made in the English Channel also which confirm our former results, and show that such of the observations of the French surveyors referred to in p. 708 as have been tested, were in excess, as had been anticipated.—F. W. B.

Explanation of the Plates.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Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Lundy I.
Port Talbot
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Hartland Pt.
Ilfracombe
Bideford
Padstow
Cardiff
Chepstow
R. Severn
Scilly Is.
Penzance
Portlock
Bridgewater
Wolf R.
Lands End
Falmouth
Fowey
Lizard Pt.
Burnham
Plymouth
Exeter
Eddystone
Dartmouth
Start Pt.
Lyme Regis
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Weymouth
Portland Bill
Swanage
Poole
Southampton
Isle of Wight
Ushant I.
Casquets
Alderney
Guernsey
Sept Isles
I. de Batz
Brest
Brehat
Sercq
La Hogue
Cherbourg
C. Barfleur
C. Carteret
48
Jersey
Minquiers
Carentan
de Penmark
Quimper Corentin
S. Brieux
C. Frehel
Granville
S. Malo
Glenan Is.
L'Orient
Port Louis
Avranches
Caen
Honfleur
R. Seine
Havre
Pontorson
Belle I.
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FRANCE
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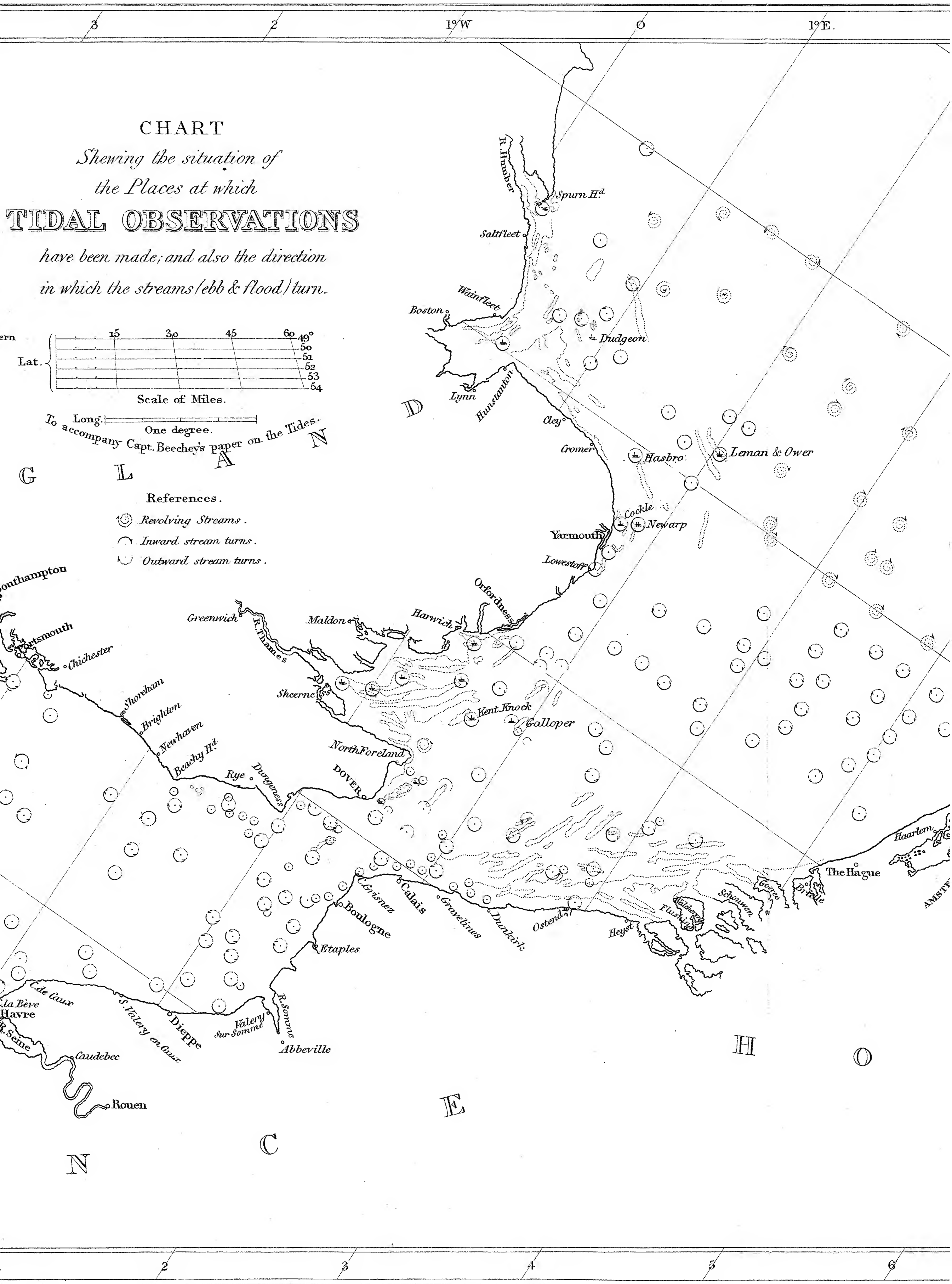
CHART
Shewing the situation of
the Places at which
TIDAL OBSERVATIONS
have been made; and also the direction
in which the streams (ebb & flood) turn.
Lat.
49° 50 51 52 53 54
15 30 45 60
Scale of Miles.
Long.
One degree.
To accompany Capt. Beechey's paper on the Tides.
References.
Revolving Streams.
Inward stream turns.
Outward stream turns.
3
2
1°W
0
1°E.
R. Humber
Spurn Hd
Saltfleet
Wainfleet
Boston
Dudgeon
Lynn
Hunstanton
Cley
Cromer
Hasbro
Leman & Ower
Cockle
Newarp
Yarmouth
Lowestoff
Orfordness
Harwich
Maldon
Greenwich
R. Thames
Sheerness
Kent Knock
Galloper
North Foreland
DOVER
Southampton
Portsmouth
Chichester
Shoreham
Brighton
Newhaven
Beachy Hd
Rye
Dungeness
C. Grisnez
Calais
Gravelines
Dunkirk
Ostend
Heyst
Flushing
Walcheren
Schouwen
Goree
Brielle
The Hague
Haarlem
Boulogne
Etaples
R. Somme
Abbeville
Valery Sur Somme
Dieppe
S. Valery en Caux
C. de Caux
C. la Bève
Havre
R. Seine
Caudebec
Rouen
E N G L A N D
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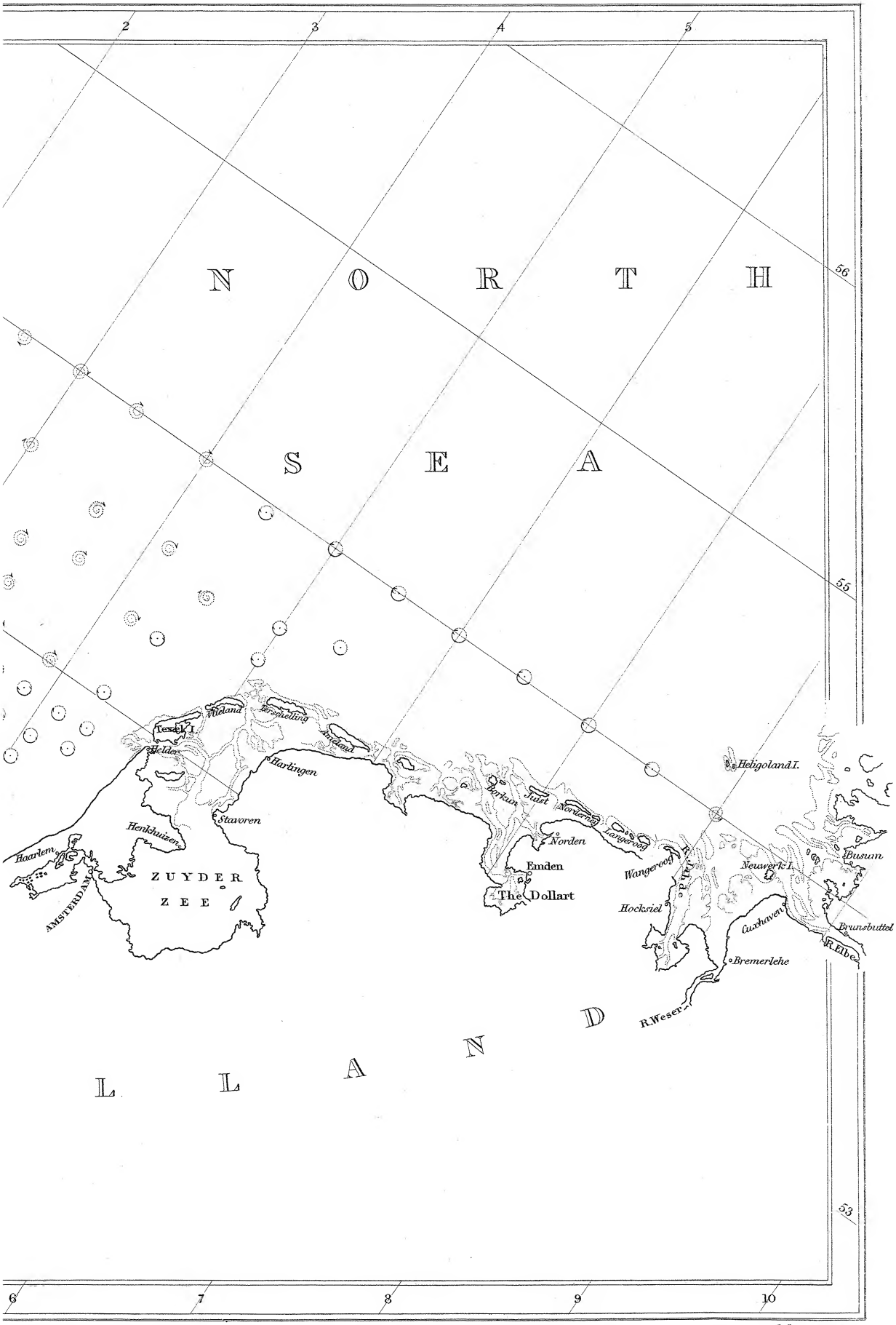
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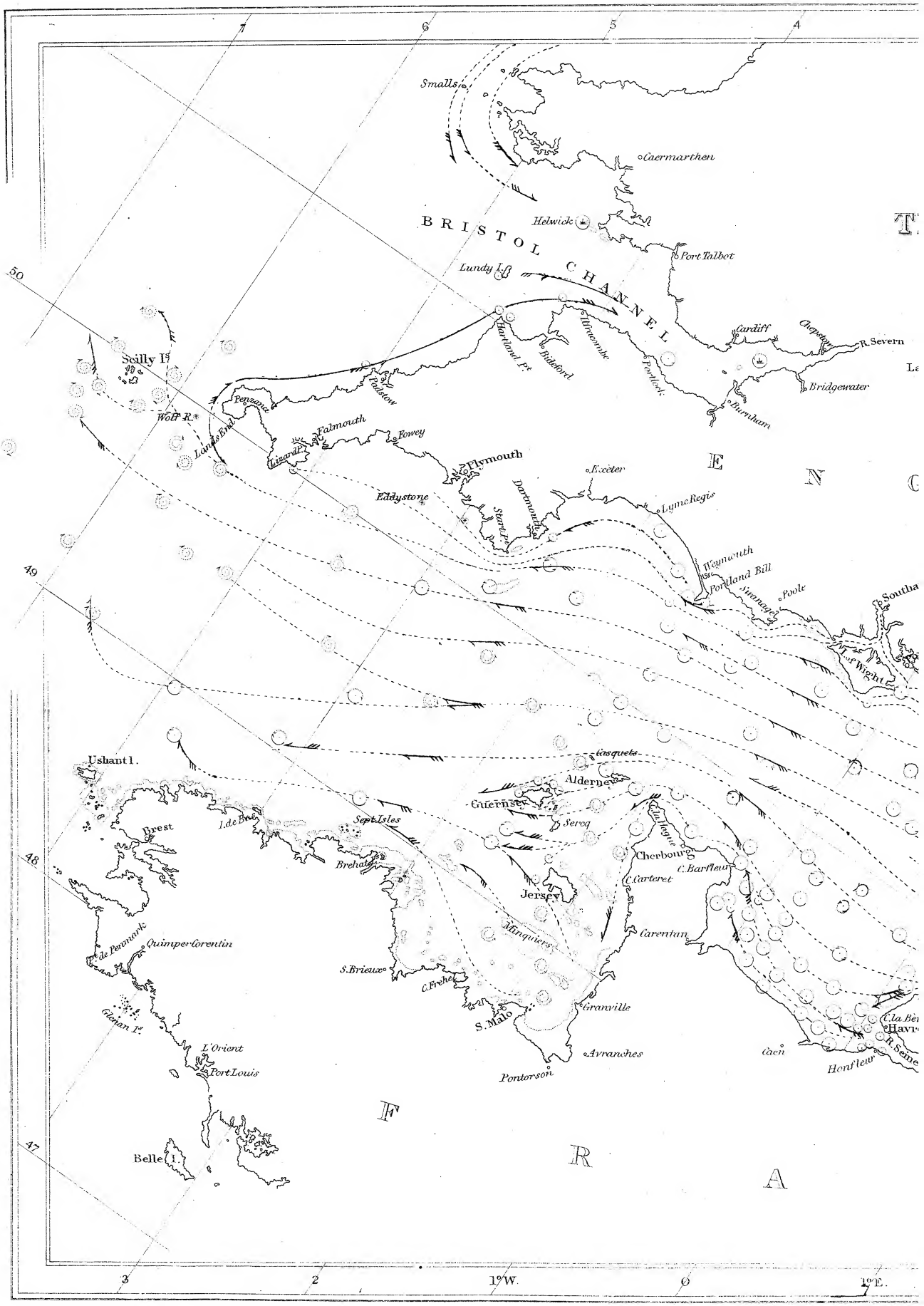
N O R T H
S E A
L L A N D
Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Heligoland I.
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
Jade
Hocksiel
Neuwerk I.
Husum
Cuxhaven
R. Elbe
Brunsbuttel
Bremerlehe
R. Weser
Staveren
Henkhuizen
Haarlem
AMSTERDAM
ZUYDER
ZEE

J. Basire sc.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Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Port Talbot
Lundy I.
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Scilly Is
Hartland Pt.
Ilfracombe
Bideford
Portlock
Cardiff
Chepstow
R. Severn
Bridgewater
Burnham
Padstow
Penzance
Wolf R.
Lands End
Falmouth
Fowey
Lizard
Plymouth
E. cster
Eddystone
Dartmouth
Start Pt.
Lyme Regis
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Weymouth
Portland Bill
Swanage
Poole
Southa
I. of Wight
Ushant I.
Casquets
Alderney
Guernsey
Sept Isles
I. de Bas
Brest
Brehat
Sercq
La Hogue
Cherbourg
C. Barfleur
C. Carteret
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Jersey
Minquiers
Carentan
de Penmark
Quimper-Corentin
S. Brieux
C. Frehel
Granville
S. Malo
Glenan Is.
L'Orient
Port Louis
Avranches
Pontorson
Caen
Honfleur
R. Seine
Belle I.
47
FRANCE
3
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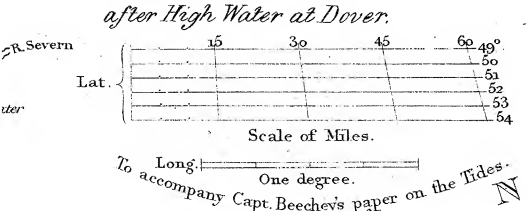
CHART

Shewing the situation of the Places at which

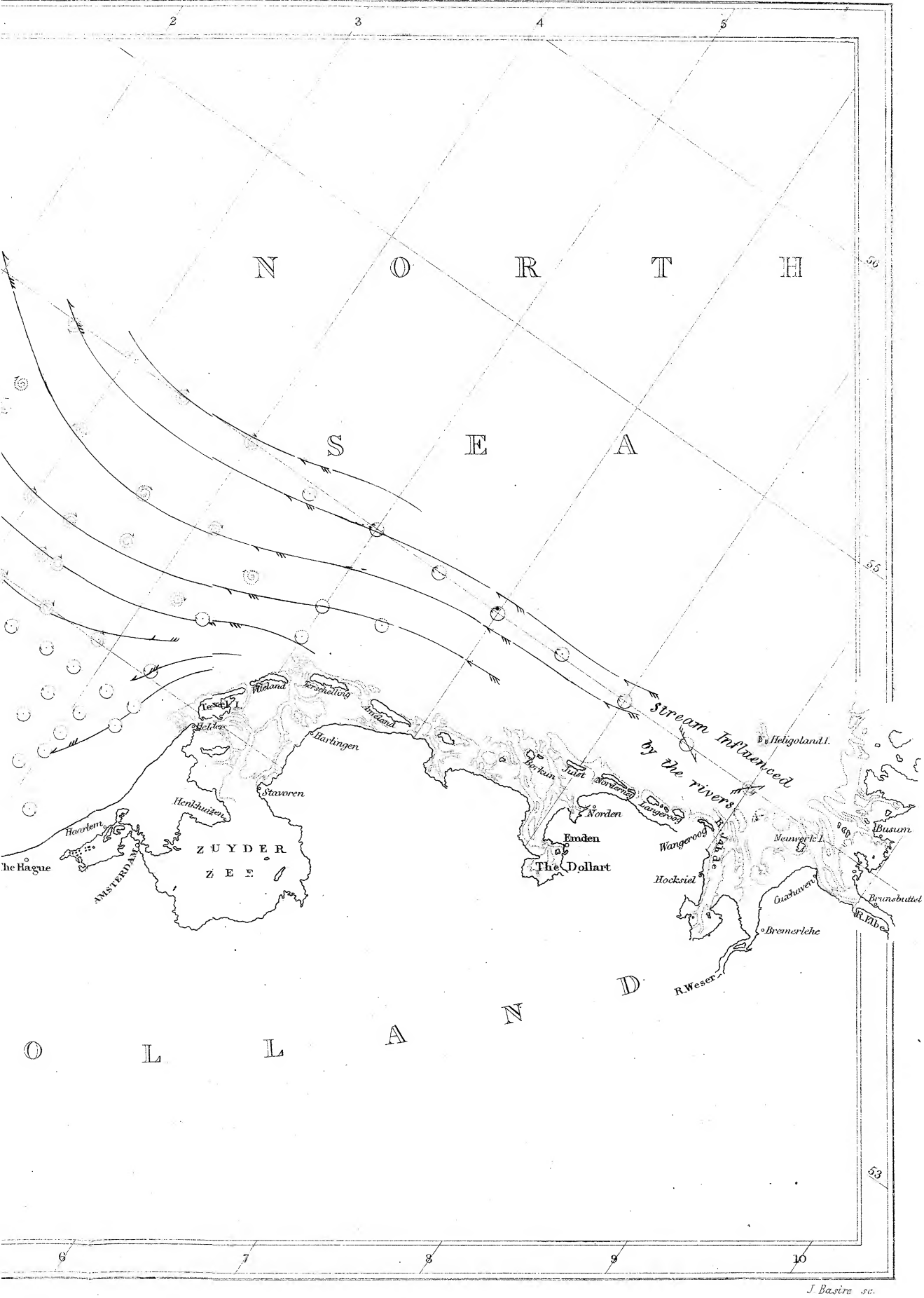
TIDAL OBSERVATIONS

have been made; and also the direction in which the streams run at 1 Hour after High Water at Dover.



References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.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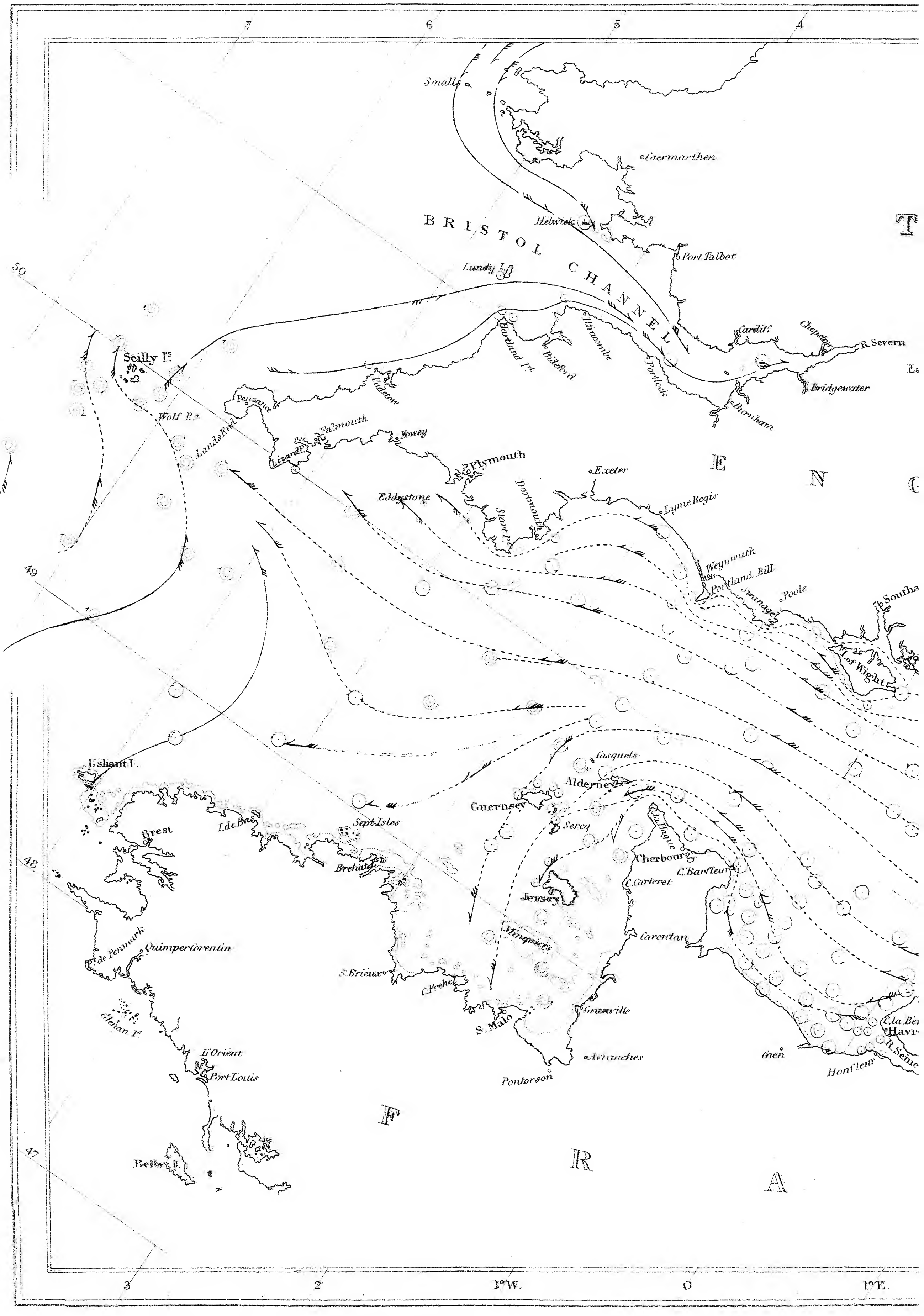
N O R T H
S E A
O L L A N D
Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Stavoren
Henkhuizen
Haarlem
The Hague
AMSTERDAM
ZUYDER
ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
Jade R.
Hocksiel
Neuwerk I.
Busum
Brunsbuttel
R. Elbe
Cuxhaven
Bremerlehe
R. Weser
Heligoland I.
stream Influenced
by the rivers

J. Basire sc.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Bridgewater
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Lands End
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Falmouth
Fowey
Plymouth
Exeter
Eddystone
Dartmouth
Start Pt.
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Weymouth
Portland Bill
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Poole
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Casquets
Alderney
Guernsey
Sercq
La Hogue
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C. Carteret
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Brehat
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C. Frehel
S. Malo
Granville
Avranches
Pontorson
Caen
Honfleur
R. Seine
C. la Bè
Havr
Pe. de Penmark
Quimpercorentin
Glenan Is.
L'Orient
Port Louis
Belle I.
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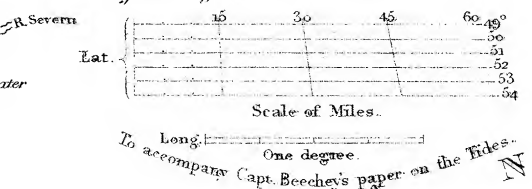
CHART

Shewing the situation of the Places at which

TIDAL OBSERVATIONS

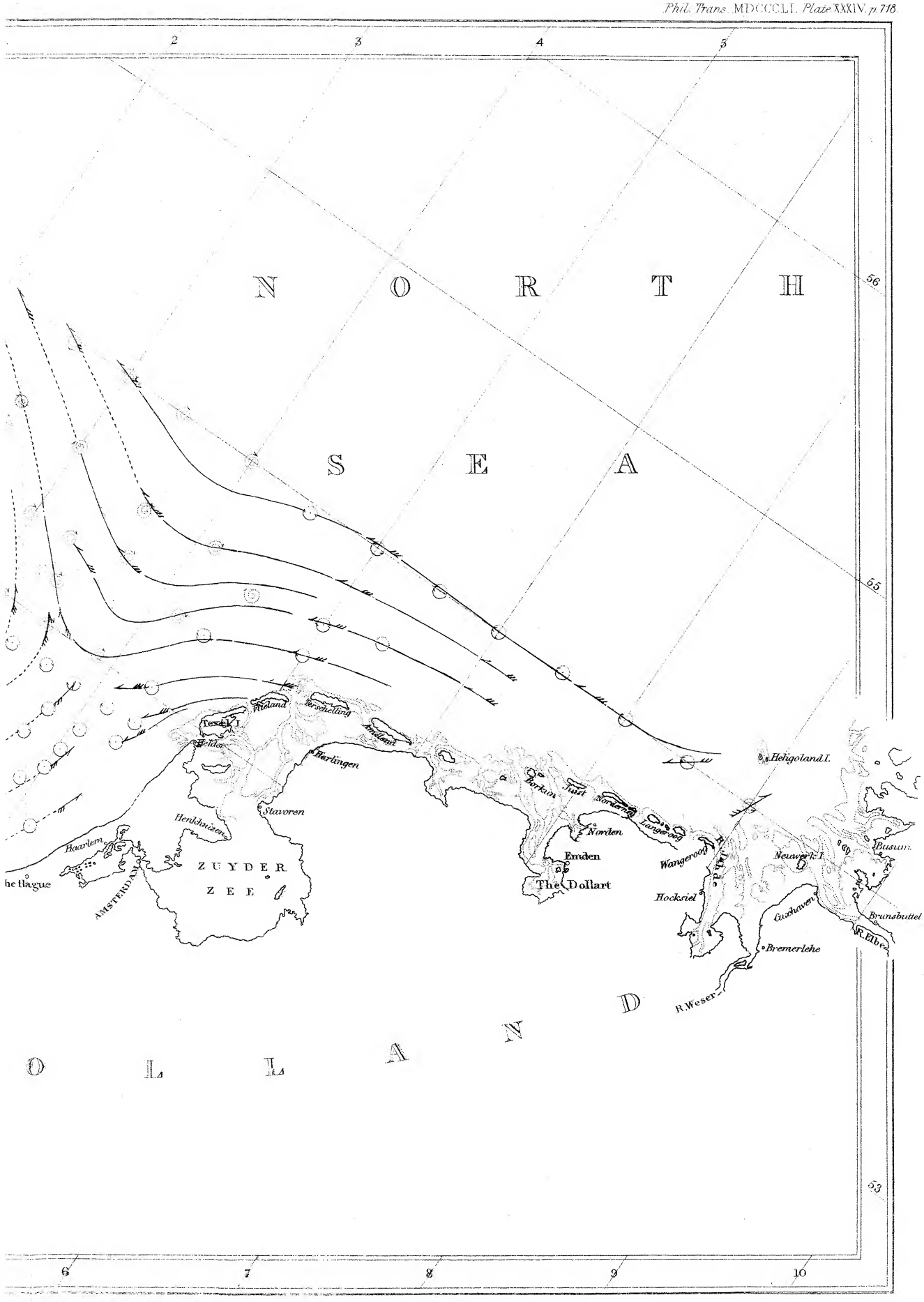
have been made: and also the direction in which the streams run at 2 Hours after High Water at Dover.



To accompany Capt. Beechey's paper on the Tides.

References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.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N O R T H
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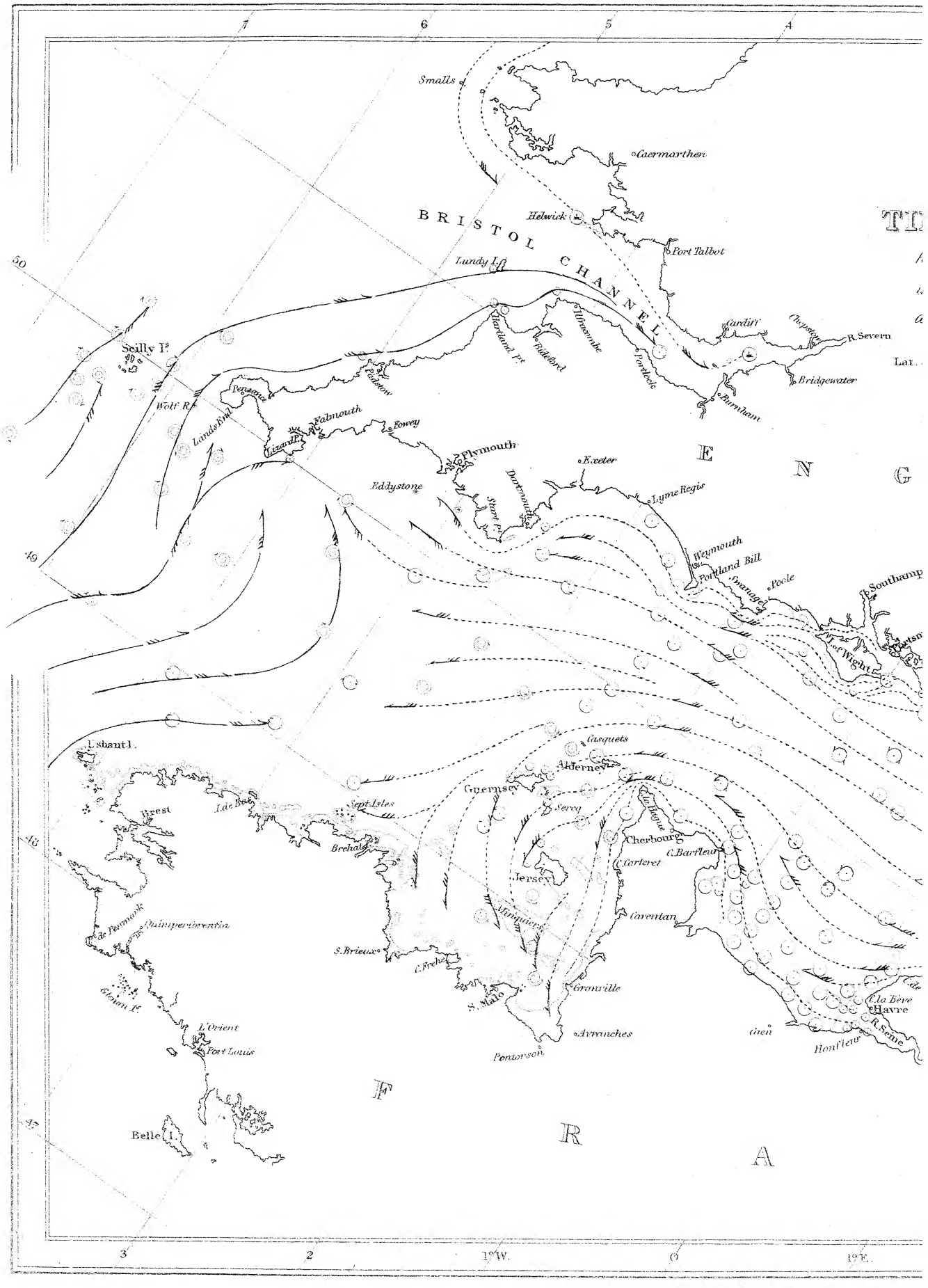
Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Stavoren
Henkhuizen
Haarlem
AMSTERDAM
he Hague
ZUYDER
ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
Helgoland I.
Neuwerk I.
Busum
Hocksiel
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser
H O L L A N D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Helwick
BRISTOL CHANNEL
Port Talbot
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Cardiff
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R. Severn
Scilly Is
Hartland Pt
Ilfracombe
Ilfracombe
Portlock
Bridgewater
Wolf R.
Penzance
Padstow
Burnham
Lands End
Falmouth
Fowey
Plymouth
Exeter
E N G
Eddystone
Dartmouth
Start Pt
Lyme Regis
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Weymouth
Portland Bill
Swanage
Poole
Southamp
Isle of Wight
Ushant I.
Casquets
Alderney
Guernsey
Sept Isles
Serq
Cherbourg
C. Barfleur
Carteret
Jersey
Brehat
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Carentan
Granville
S. Malo
Avranches
Pontorson
Honfleur
R. Seine
Havre
Belle I.
F
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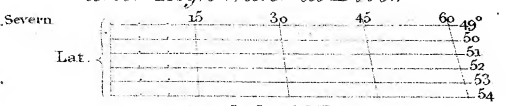
CHART

Shewing the situation of the Places at which

TIDAL OBSERVATIONS

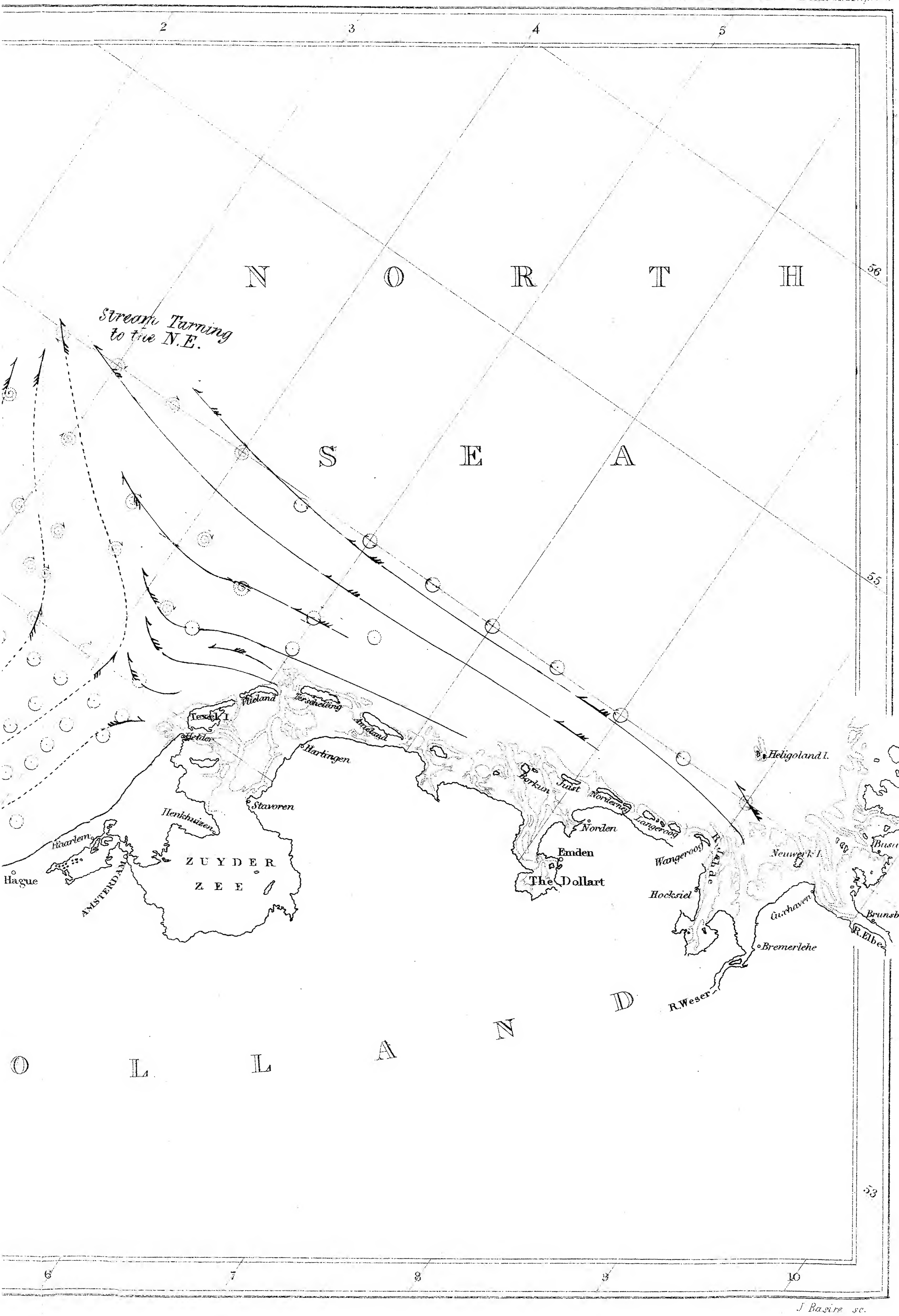
have been made; and also the direction in which the streams run at 3 Hours after High Water at Dover.



To accompany Capt. Beechey's paper on the Tides.

References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.



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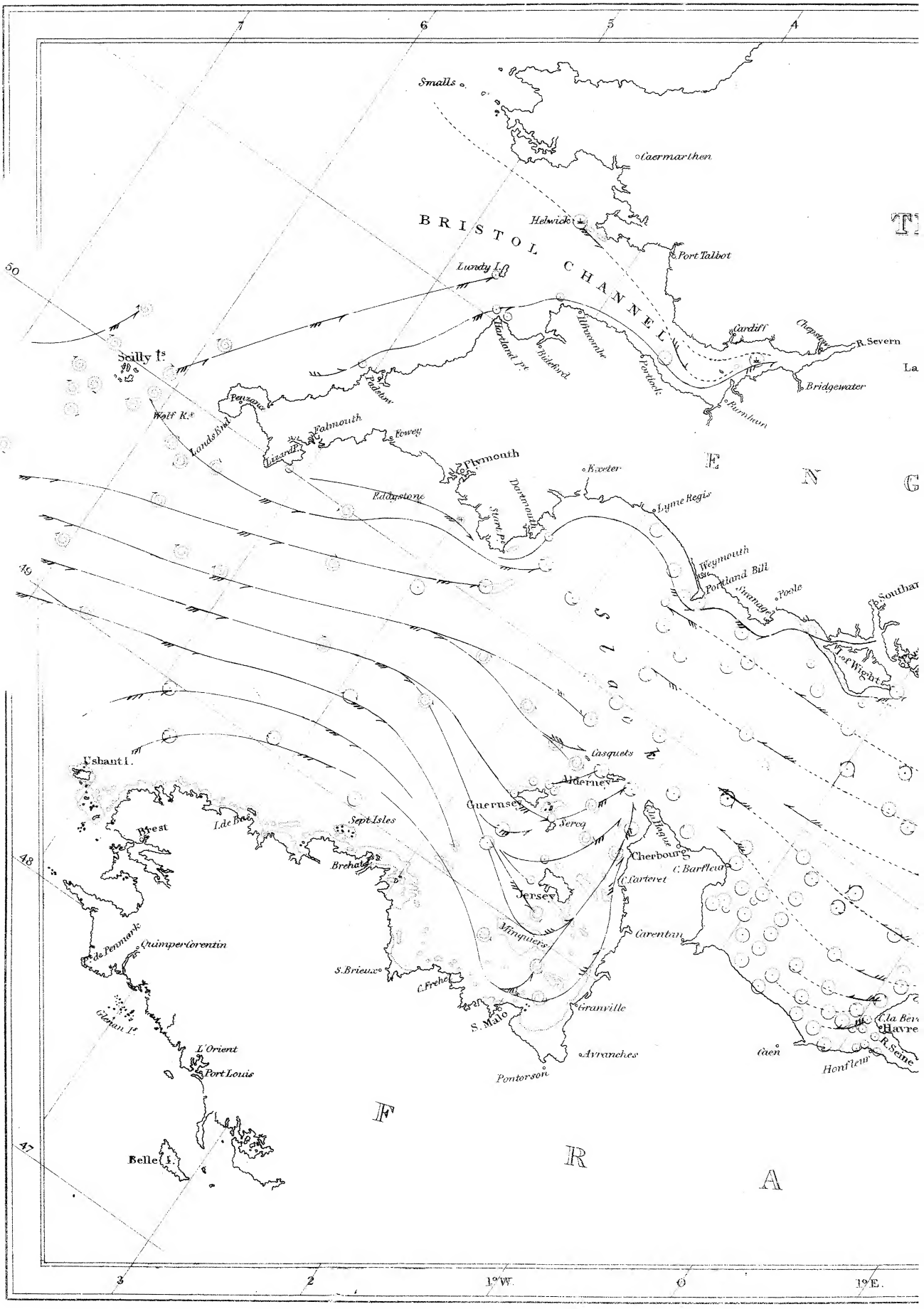
NORTH SEA
Stream Turning to the N.E.
Vlieland
Terschelling
Ameland
Texel I.
Helder
Hartingen
Stavoren
Henkhuizen
Haarlem
Hague
AMSTERDAM
ZUYDER ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
R. Jade
Hocksiel
Heligoland I.
Neuwerk I.
Busum
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser
HOLLAND

J. Basire sc.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6
5
4
Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Port Talbot
Lundy I.
50
Cardiff
Chepstow
R. Severn
Scilly Is.
Hartland Pt.
Ilfracombe
Bideford
Portlock
Bridgewater
Penzance
Falmouth
Fowey
Plymouth
Exeter
Eddystone
Dartmouth
Lyme Regis
Weymouth
Portland Bill
Swanage
Poole
Southar
I. of Wight
49
Ushant I.
Casquets
Alderney
Guernsey
Sept Isles
Brest
I. de Batz
Sercq
La Hague
Cherbourg
C. Barfleur
48
Brehat
C. Carteret
Jersey
Minquiers
Carentan
C. de Penmark
Crimpe
Lorentin
S. Brieux
C. Frehel
Granville
Glenan Is.
S. Malo
L'Orient
Port Louis
Avranches
Caen
Honfleur
R. Seine
Pontorson
47
Belle I.
3
2
1°W.
0
1°E.

CHART

Shewing the situation of the Places at which

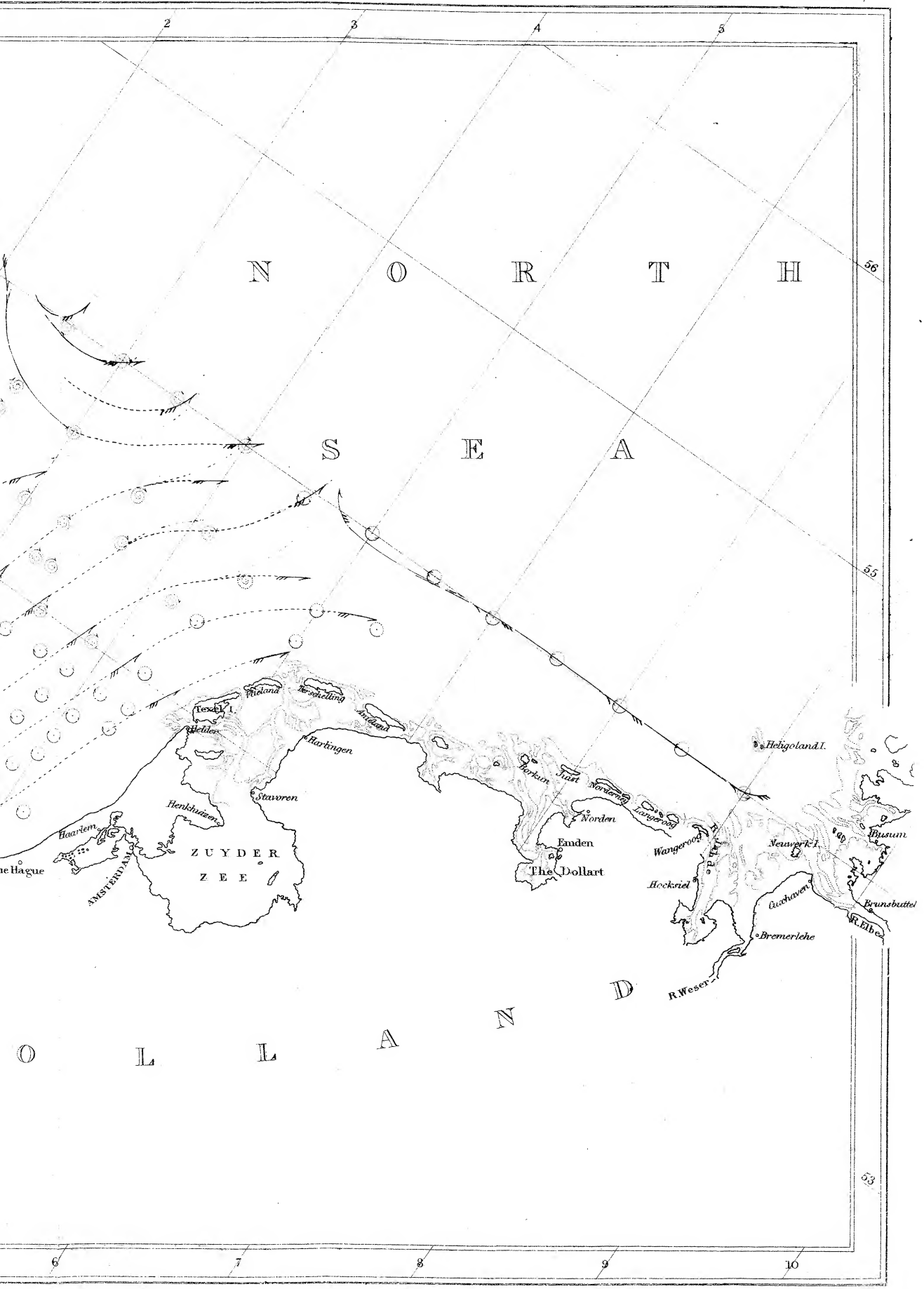
TIDAL OBSERVATIONS

have been made; and also the direction in which the streams run at 6 Hours after High Water at Dover

To accompany Capt. Beechey's paper on the Tides.

References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.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56
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53
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8
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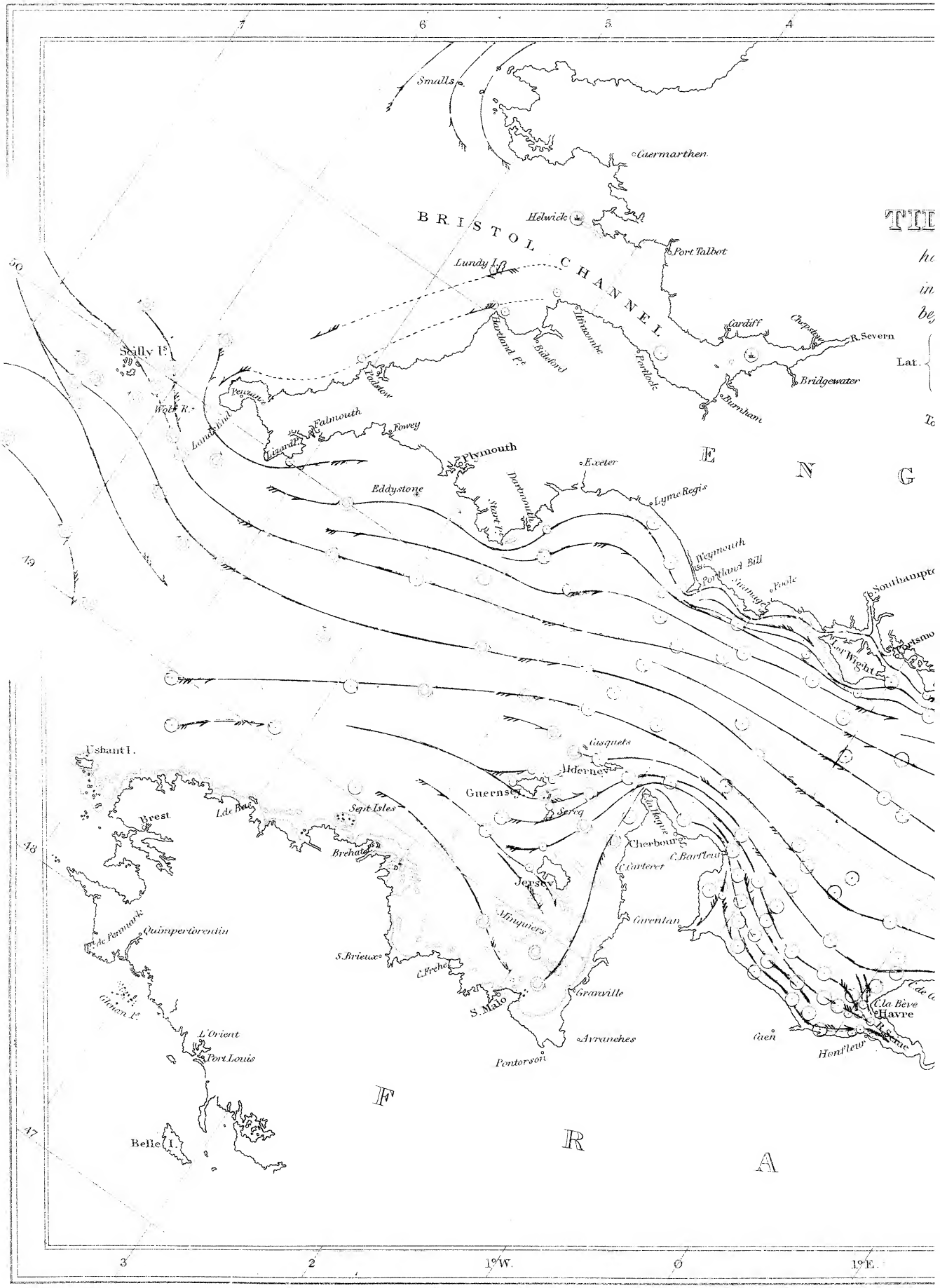
10
N O R T H
S E A
O L L A N D
Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Stavoren
Henkhuizen
Haarlem
AMSTERDAM
ZUYDER
ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
Hooksiel
Heligoland I.
Neuwerk I.
Busum
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser
J. Basire sc.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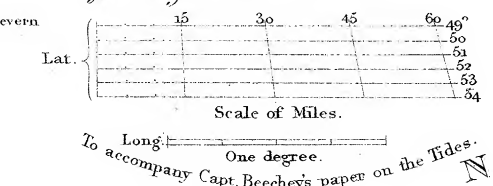
4
Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Lundy I.
Port Talbot
Cardiff
Chepstow
R. Severn
Hartland Pt.
Ilfracombe
Bridgewater
Scilly Is.
Padstow
Pendennis
Falmouth
Fowey
Plymouth
Exeter
Eddystone
Dartmouth
Lyme Regis
Weymouth
Portland Bill
Poole
Southampton
Isle of Wight
Ushant I.
Brest
Sept Isles
Guernsey
Sercq
Jersey
Cherbourg
C. Barfleur
C. Carteret
Minquiers
Quiberon
S. Brieux
C. Frehel
S. Malo
Granville
Avranches
Pontorson
C. la Hève
Havre
Honfleur
Belle I.
L'Orient
Port Louis
Glénan I.
50
49
48
47
3
2
1°W.
0
1°E.

CHART

Shewing the situation of the Places at which

TIDAL OBSERVATIONS

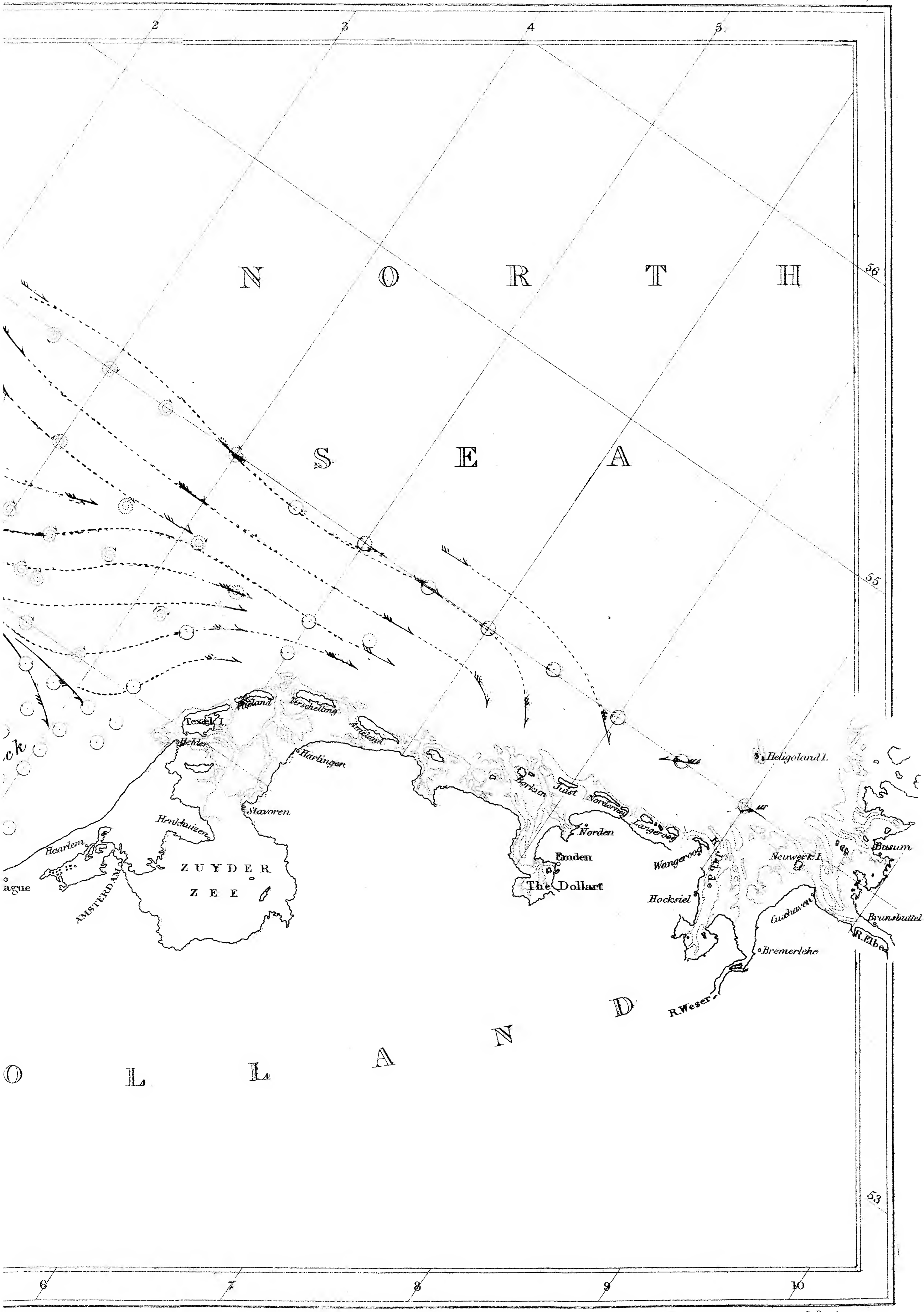
have been made; and also the direction in which the streams run at 5 Hours before High Water at Dover.



To accompany Capt. Beechey's paper on the Tides.

References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.


2
3
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N O R T H
S E A
H O L L A N D
56
55
53
Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Stavoren
Henkhuizen
Haarlem
Hague
AMSTERDAM
ZUYDER ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
R. Jahde
Hocksiel
Heligoland I.
Neuwerk I.
Busum
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser
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7
8
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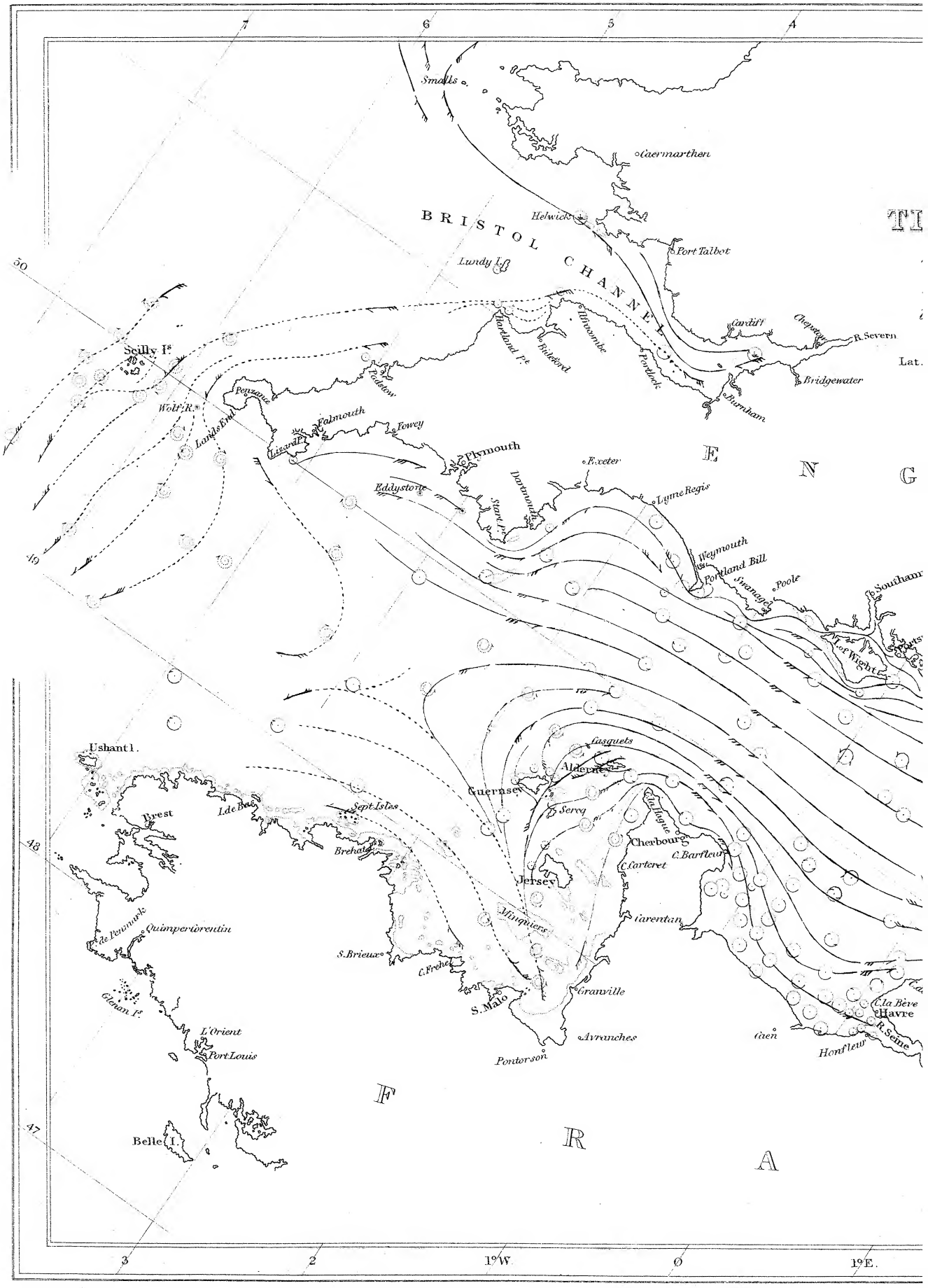
10

J. Basire sc.


7
6
5
4
Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Port Talbot
Lundy I.
50
Cardiff
Chepstow
R. Severn
Scilly Is
Hartland Pt.
Ilfracombe
Bideford
Portlock
Lat.
Bridgewater
Wolf R.
Penzance
Falmouth
Fowey
Lizard Pt.
Lands End
Plymouth
Exeter
Eddystone
Dartmouth
Start Pt.
Lyme Regis
49
Weymouth
Portland Bill
Swanage
Poole
R. Southam
I. of Wight
Ushant I.
Lusquets
Alderney
Guernsey
Sept Isles
L. de Batz
Brest
Sercq
La Hague
Cherbourg
C. Barfleur
48
Brehat
C. Carteret
Jersey
Minquiers
Carentan
de Penmarck
Quimperlorentin
S. Brieux
C. Frehel
Granville
C. la Bève
Havre
Glenan Is
S. Malo
L'Orient
Port Louis
Avranches
Caen
R. Seine
Honfleur
Pontorson
47
Belle I.
3
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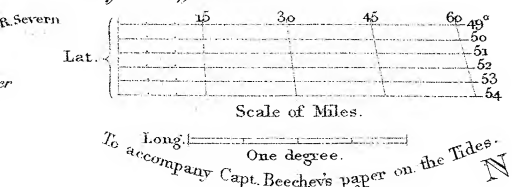
1°W
0
1°E.

CHART

Shewing the situation of the Places at which

TIDAL OBSERVATIONS

have been made: and also the direction in which the streams run at 3 Hours before High Water at Dover.

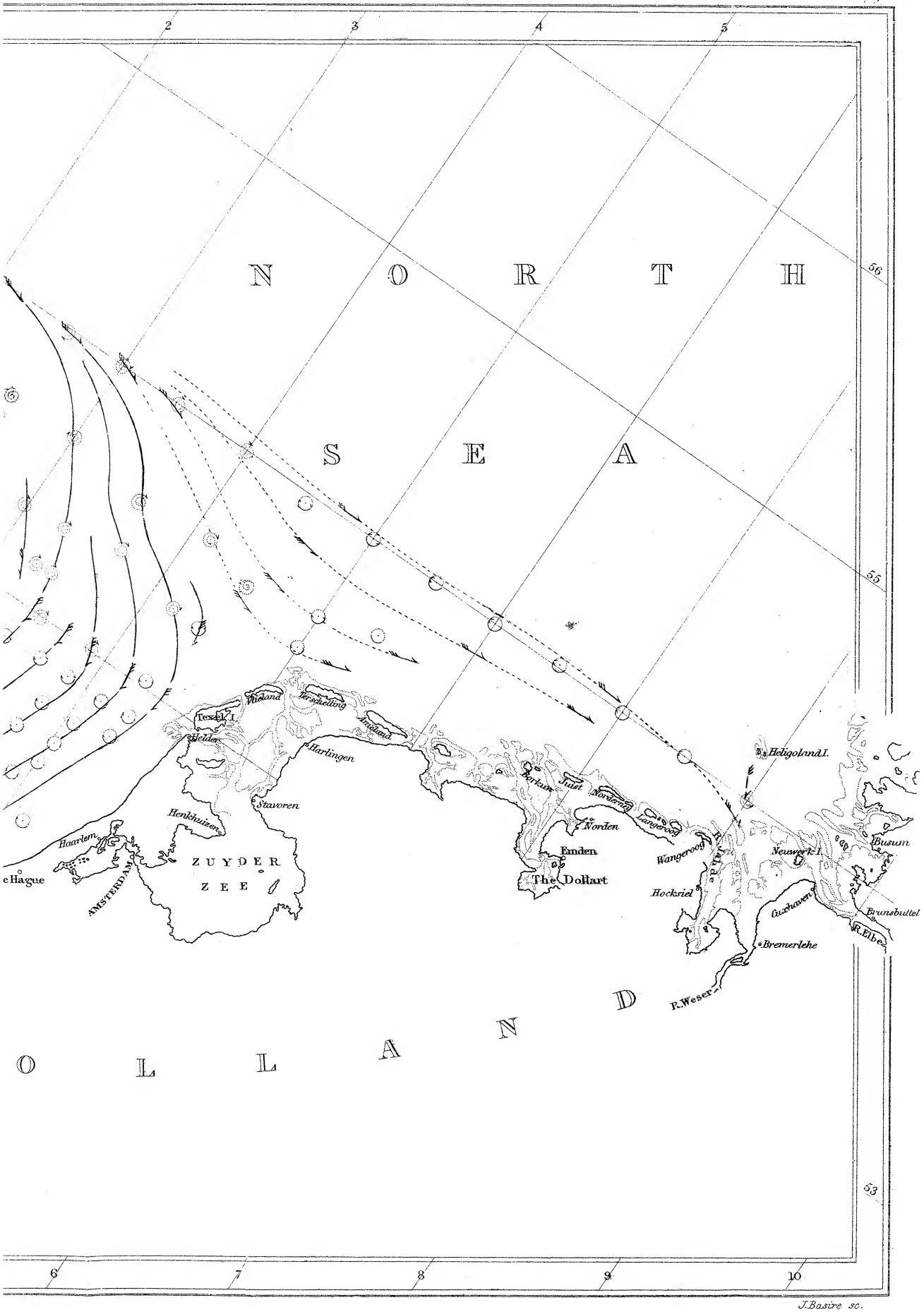


To accompany Capt. Beechey's paper on the Tides.

References.

- Revolving Streams.
- Inward stream turns.
- Outward stream turns.

R. Severn
R. Humber
Spurn Hd.
Saltfleet
Wainfleet
Boston
Dudgeon
Lynn
Hunstanton
Cley
Gromer
Hasbro
Lemon & Ower
Cockle
Newarp
Yarmouth
Lowestoft
Orfordness
Harwich
Maldon
Greenwich
R. Thames
Sheerness
Kent Knock
Galloper
North Foreland
DOVER
Dungeness
Rye
Beachy Hd.
Newhaven
Brighton
Shoreham
Chichester
Portsmouth
Southampton
Boulogne
Etaples
Calais
Gravelines
Dunkirk
Ostend
Heyst
Flushing
Schouwen
Goree
Brielle
The Hague
Dieppe
Valery sur Somme
Valery en Caux
R. Somme
Abbeville
C. la Hève
Havre
R. Seine
Caudebec
Rouen
Cde Caux


2
3
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53
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8
9
10
N O R T H
S E A
O L L A N D
Helgoland I.
Wieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Stavoren
Henkhuizen
Haarlem
e Hague
AMSTERDAM
ZUYDER
ZEE
Borkum
Juist
Norderney
Langeroog
Norden
Emden
The Dollart
Wangeroog
Jade R.
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Busum
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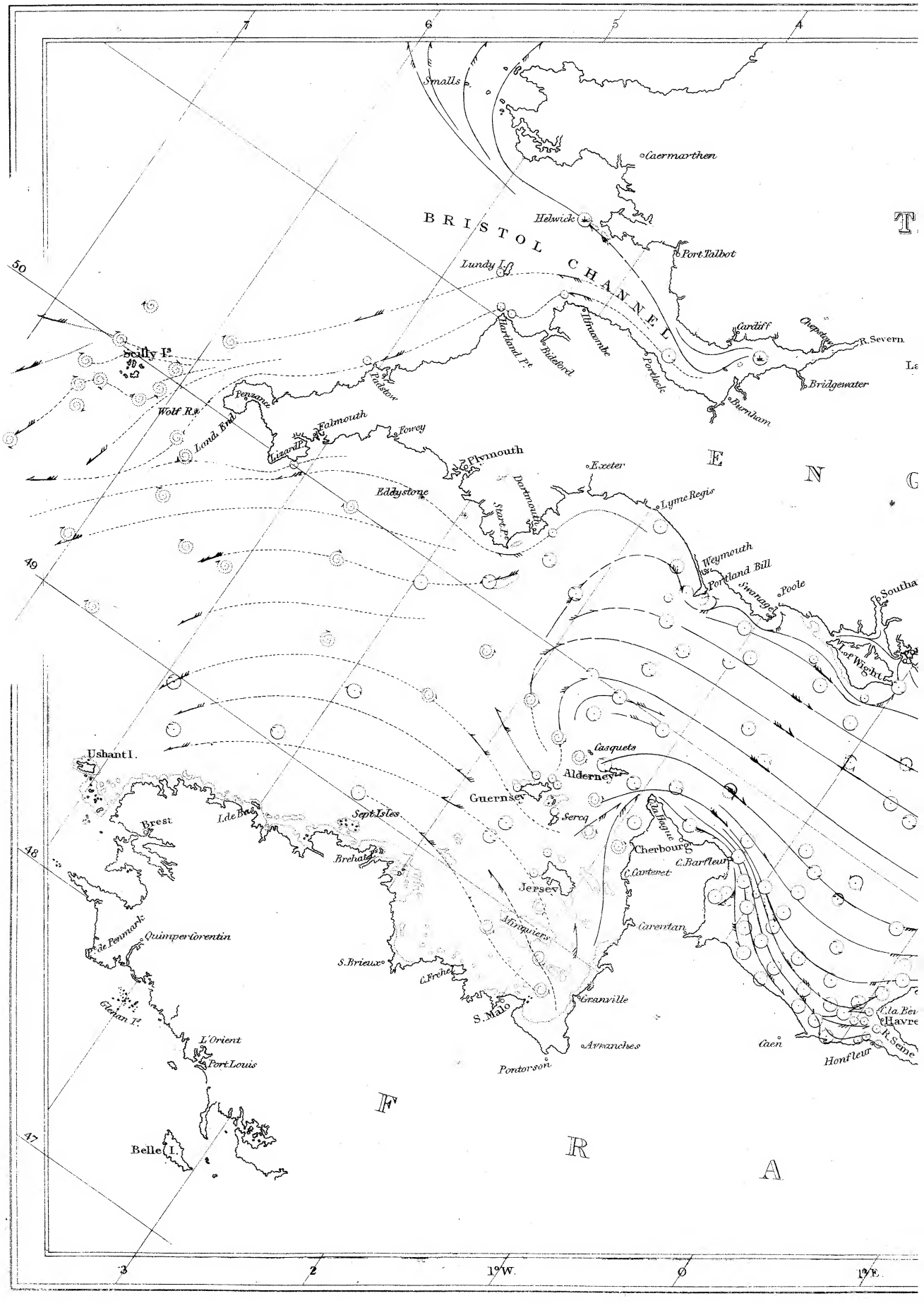
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser

J. Basire sc.


7
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Smalls
Caermarthen
BRISTOL CHANNEL
Helwick
Port Talbot
Lundy I.
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Cardiff
Chepstow
R. Severn
Scilly Is
Hartland Pt.
Ilfracombe
Bideford
Portlock
Padstow
Bridgewater
Penzance
Wolf R.
Burnham
Falmouth
Fowey
Land End
Lizard Pt.
Plymouth
Exeter
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N
G
Eddystone
Dartmouth
Start Pt.
Lyme Regis
49
Weymouth
Portland Bill
Swanage
Poole
Southa
of Wight
Ushant I.
Casquets
Alderney
Guernsey
Sercq
Brest
I. de Bas
Sept Isles
Hague
Cherbourg
C. Barfleur
48
Brehat
C. Carteret
Jersey
Minquiers
Quimperlorentin
de Penmark
Carentan
S. Brieux
C. Frehel
Granville
Glenan Is.
S. Malo
L'Orient
Port Louis
Avranches
Caen
Honfleur
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Belle I.
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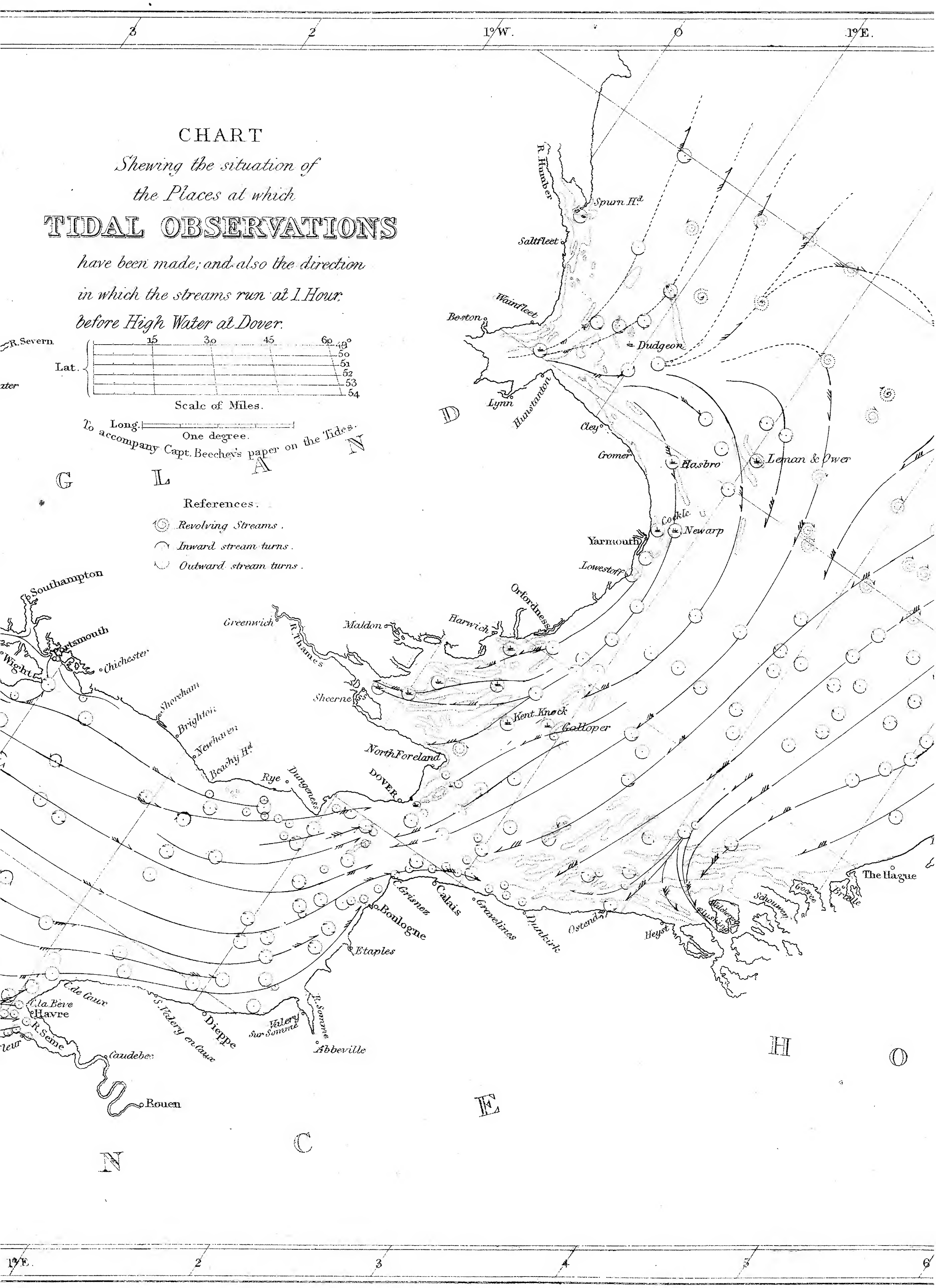
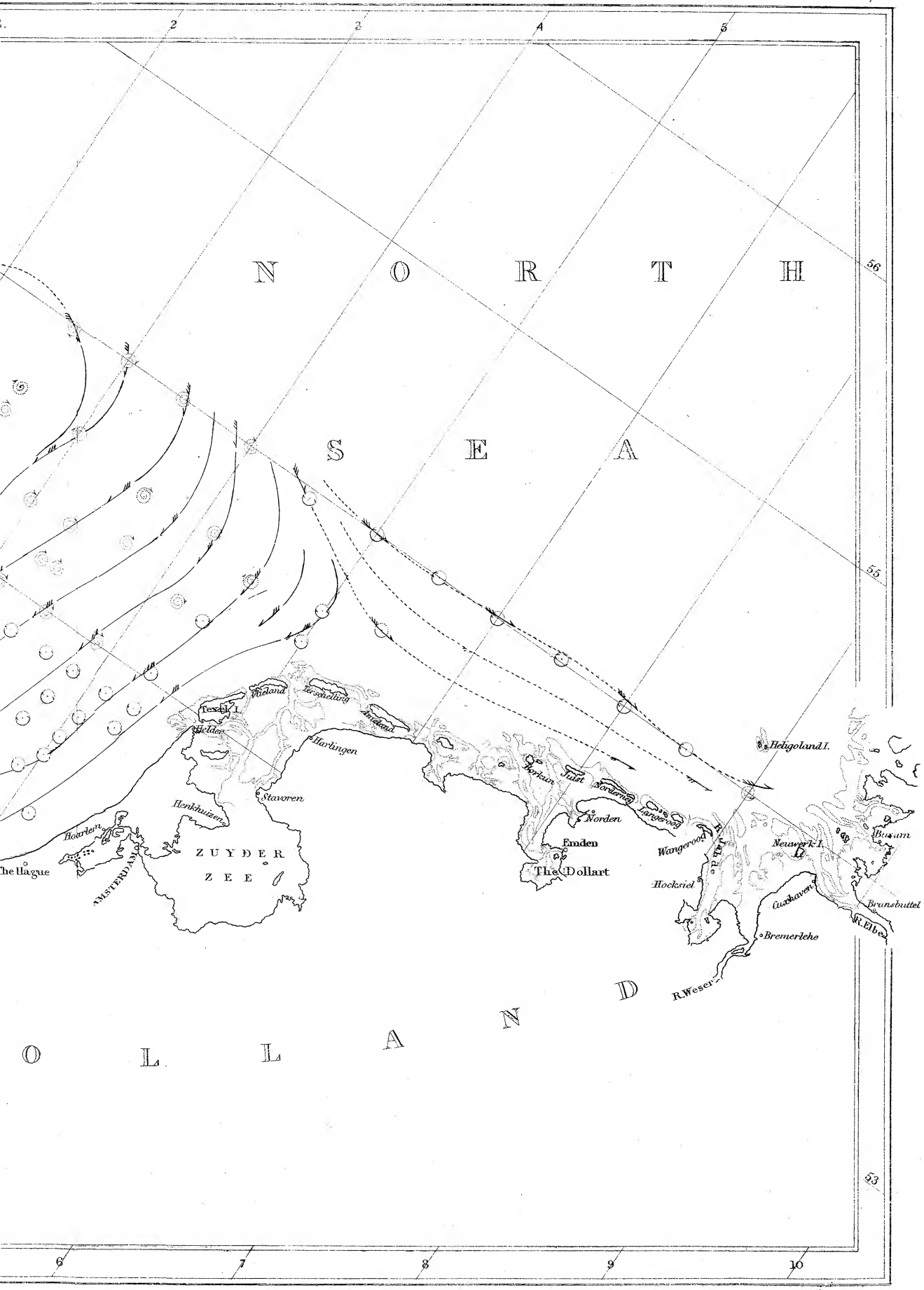


CHART
Shewing the situation of
the Places at which
TIDAL OBSERVATIONS
have been made; and also the direction
in which the streams run at 1 Hour
before High Water at Dover.
To accompany Capt. Beechey's paper on the Tides.
Lat.
Scale of Miles.
Long.
One degree.
References.
Revolving Streams.
Inward stream turns.
Outward stream turns.
1°W.
1°E.
ENGLAND
FRANCE
HOLLAND
R. Humber
Spurn Hd.
Saltfleet
Wainfleet
Boston
Dudgeon
Lynn
Hunstanton
Cley
Cromer
Hasbro
Leman & Ower
Cockle
Newarp
Yarmouth
Lowestoff
Orfordness
Harwich
Maldon
Greenwich
R. Thames
Sheerness
Kent Knock
Galloper
North Foreland
DOVER
Southampton
Portsmouth
Wight
Chichester
Shoreham
Brighton
Newhaven
Beachy Hd.
Rye
Dungeness
R. Severn
C. Grisnez
Calais
Gravelines
Dunkirk
Ostend
Heyst
Flushing
Walcheren
Schouwen
Goree
Brielle
The Hague
Boulogne
Etaples
C. de Caux
C. la Heve
Havre
R. Seine
Caudebec
Rouen
S. Valery en Caux
Dieppe
Valery Sur Somme
R. Somme
Abbeville


2
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4
5
NORTH
SEA
56
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53
6
7
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9
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Vlieland
Terschelling
Ameland
Texel I.
Helder
Harlingen
Heligoland I.
Borkum
Juist
Norderney
Langeoog
Norden
Emden
The Dollart
Wangeroog
Neuwerk I.
Hocksiel
Cuxhaven
Brunsbuttel
R. Elbe
Bremerlehe
R. Weser
Stavoren
Henkhuizen
Bouvlen
The Hague
AMSTERDAM
ZUYDER
ZEE
HOLLAND

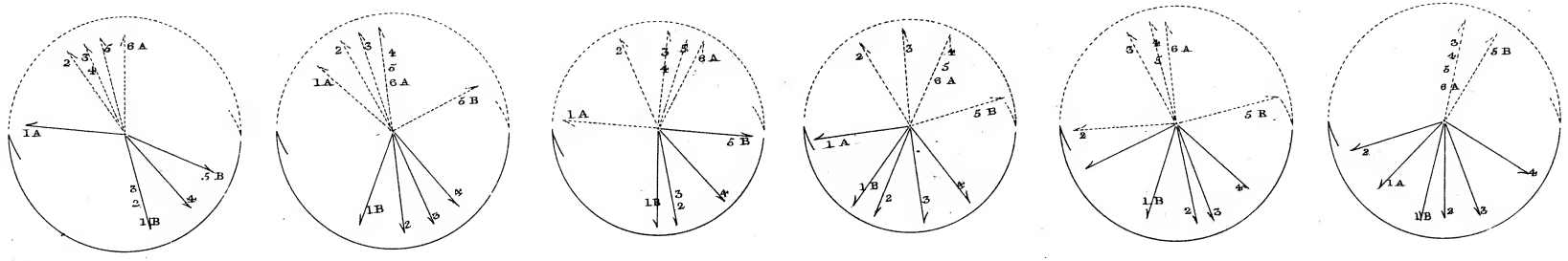
J. Basire, sc.

PLAN I.

Shewing the course of the stream both in the revolving and in the true Tides of the North Sea and English Channel.

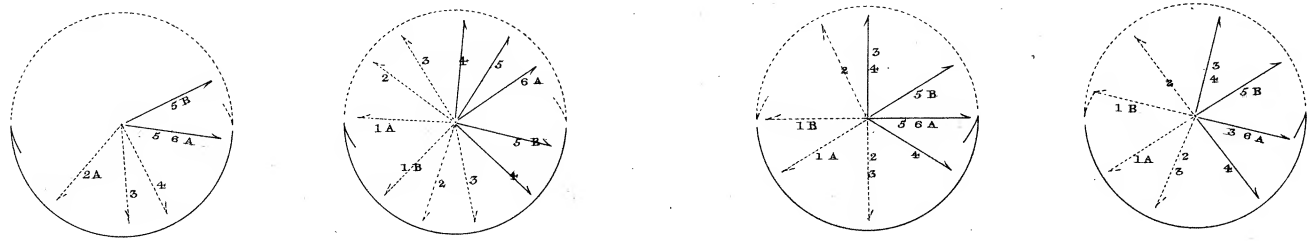
REVOLVING TIDES.

30m. from the coast of Norfolk



27 mls. off the Texel Id.

25 mls. off the Start

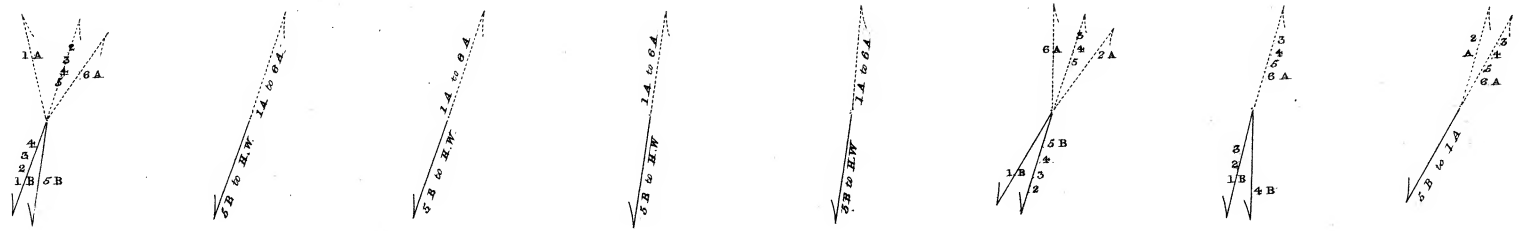


11 mls. off Guernsey

TIDES

observed in the true stream of the Channel.

11 mls. off Alboro'



11 mls. off Katwyk.

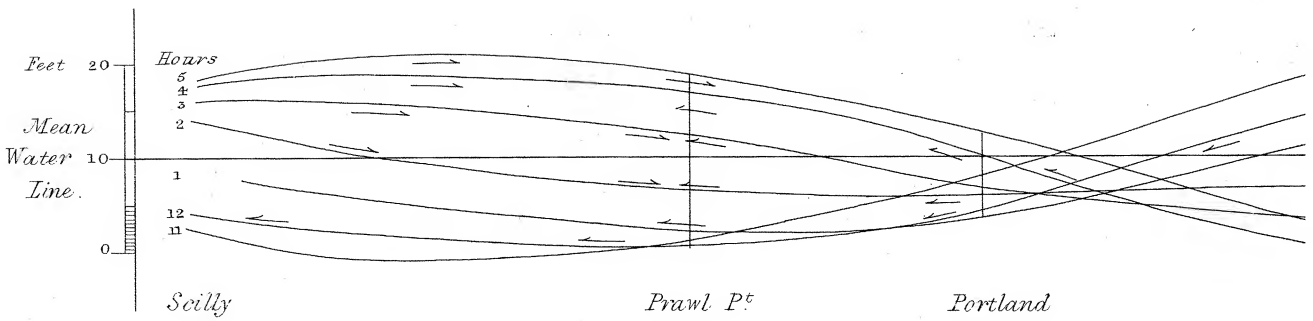
22 mls. off Portland

22 mls. off Beachey Hd.

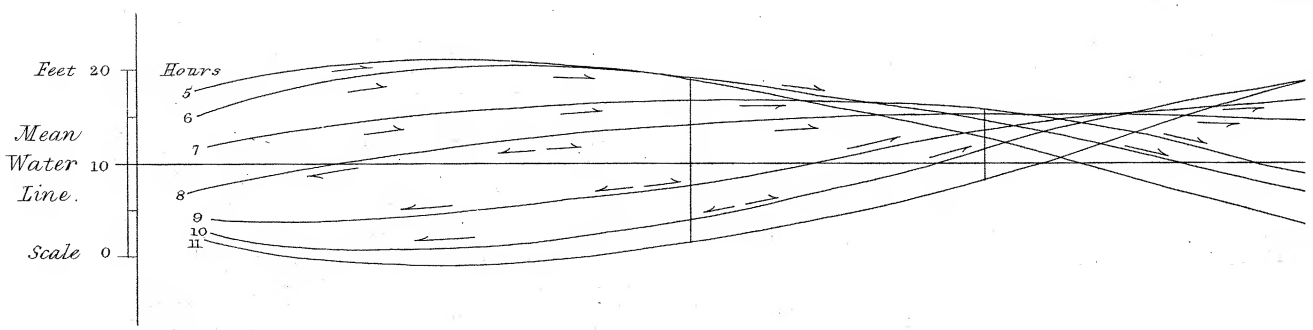
Shewing the form of the surface of the w

=

FA



RI



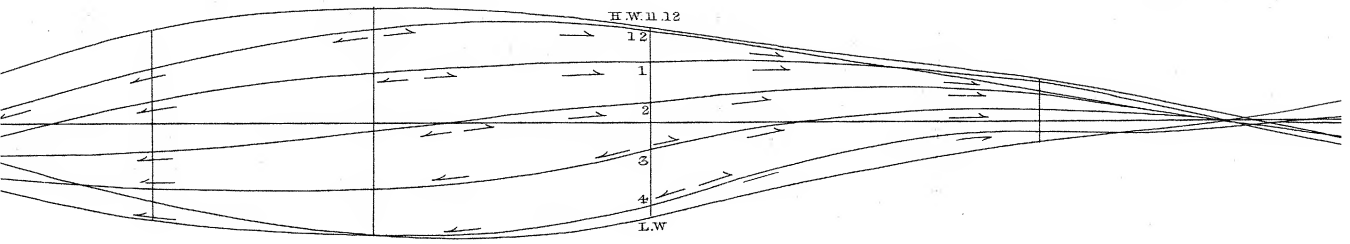
These sec

as they o

PLAN 2.

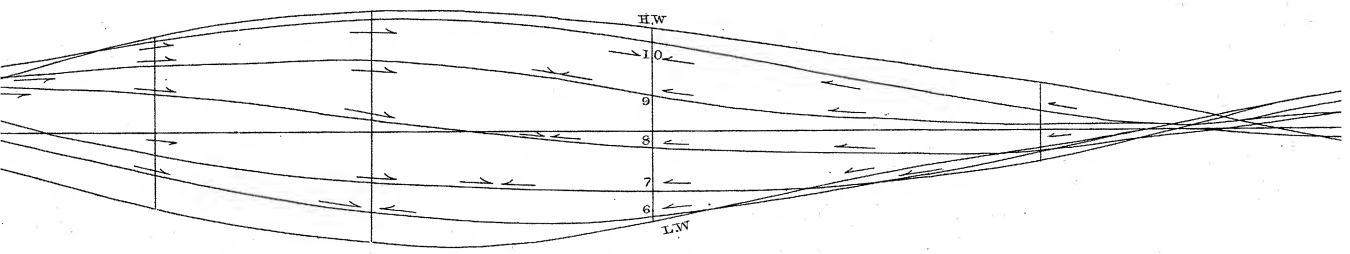
f the water. and the direction of the stream between Scilly and Spurn Pt
at each hour of the Tide.

FALLING TIDES AT DOVER.

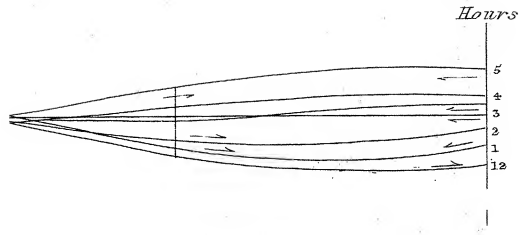


Selsea *Beachey Hd* *Dover* *Harwich*

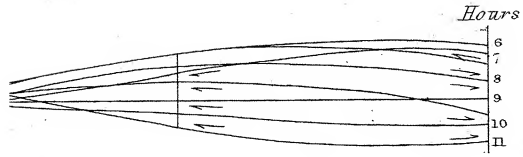
RISING TIDES AT DOVER.



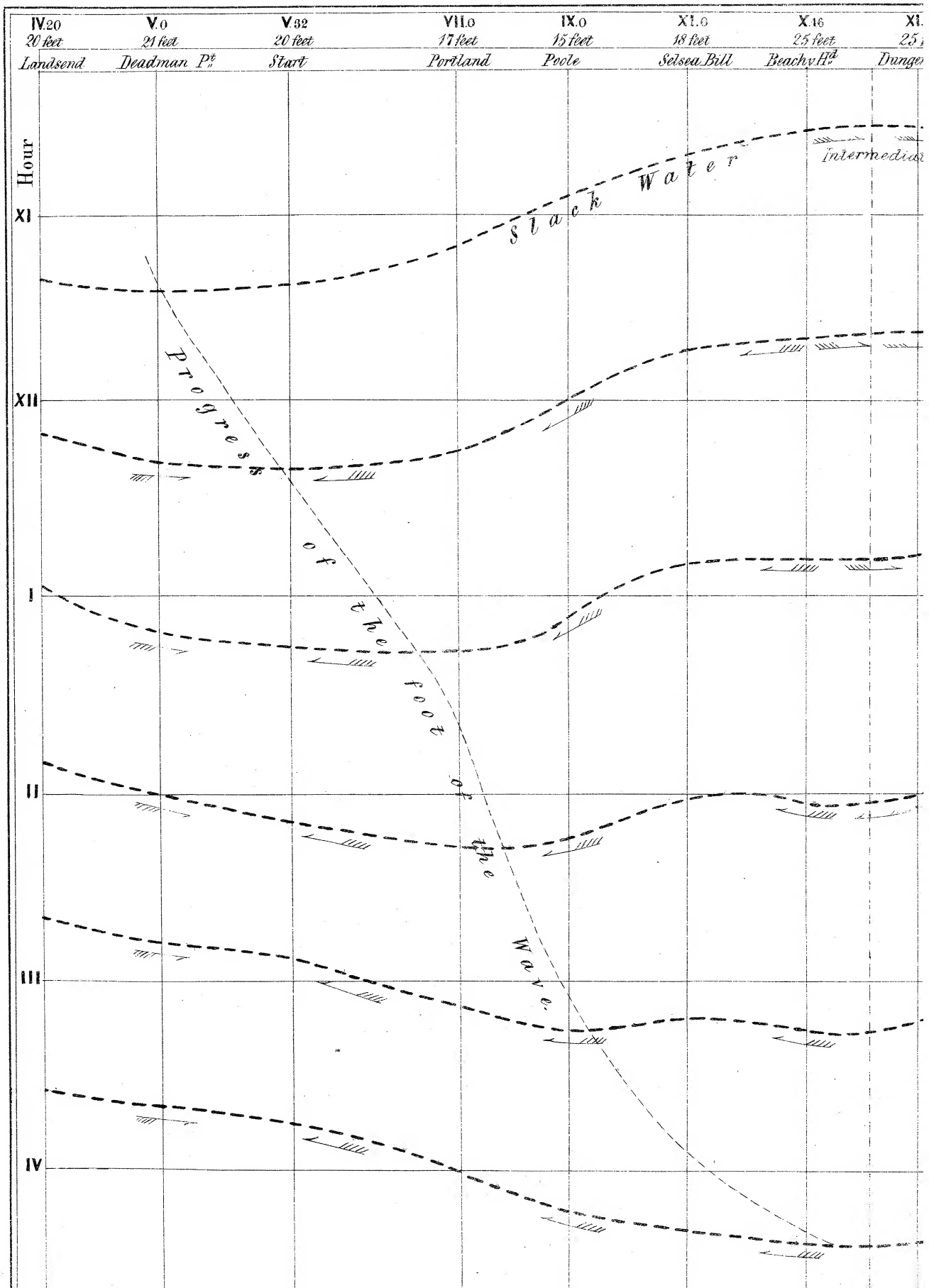
ese sections are THE MEAN *of the Wave Lines*
they occur upon the English and French Coasts.

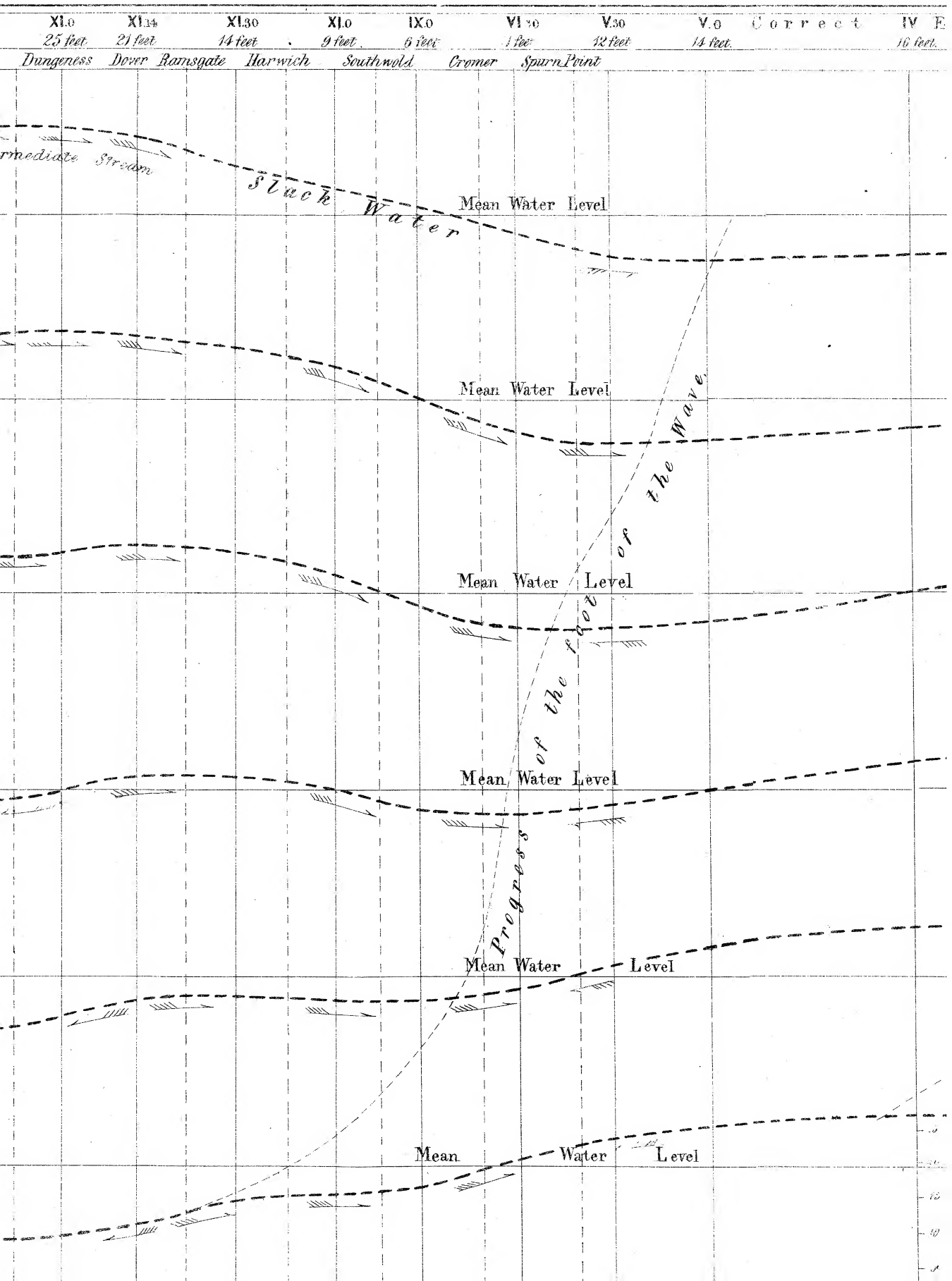


Cromer *Spurn*



J. Basire sc


IV.20
20 feet
Landsend
V.0
21 feet
Deadman P.t
V.32
20 feet
Start
VII.0
17 feet
Portland
IX.0
15 feet
Poole
X.0
18 feet
Selsea Bill
X.16
25 feet
Beachy Hd
Hour
XI
XII
I
II
III
IV
Slack Water
Intermediate
Progress
of the
foot of
the
Wave.


XI.0 XI.34 XI.30 XI.0 IX.0 VI.30 V.30 V.0 Correct IV E
25 feet 21 feet 14 feet 9 feet 6 feet 1 foot 12 feet 14 feet 16 feet
Dungeness Dover Ramsgate Harwich Southwold Cromer Spurn Point
rmediate Stream
Slack Water
Mean Water Level
Mean Water Level
Mean Water Level
Mean Water Level
Progress of the foot of the Wave
Mean Water Level
Mean Water Level

IV Establishment 16 feet. III 15 feet. Range II 15 feet. I 13 feet.

PLAN 3

Exhibiting the Exaggerated form of the surface of the Tide-wave between Cromarty and the Lands End; at every hour of the tide. (Dover Establishment.)

From data in Professor Whewell's paper on the Tides Phil. Trans 1836, and in the Annuaire des Marées des Côtes de France 1848. etc.

the direction of the stream excepted

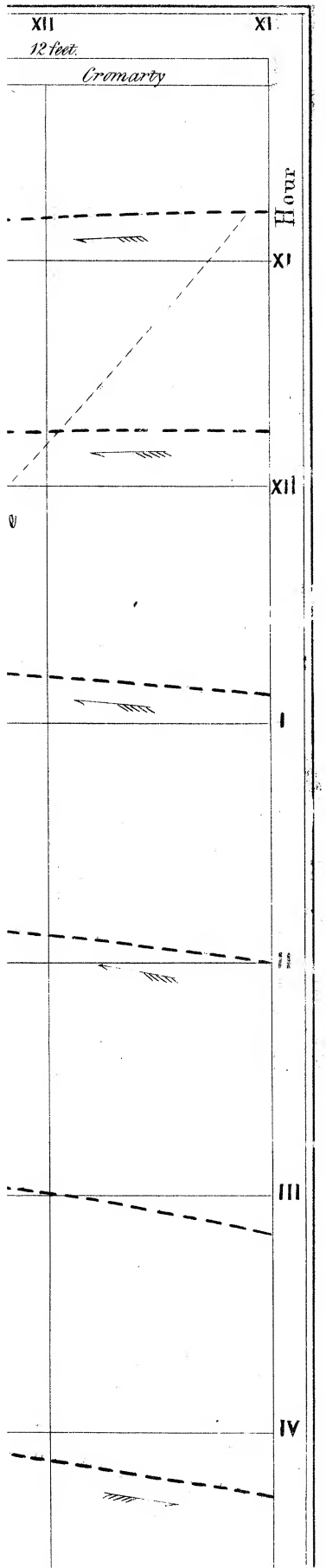
Outer Wave or Parent

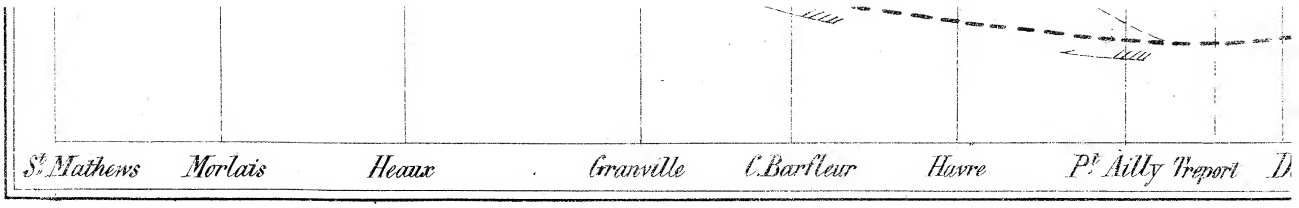
FALLING TIDES (at Dover)

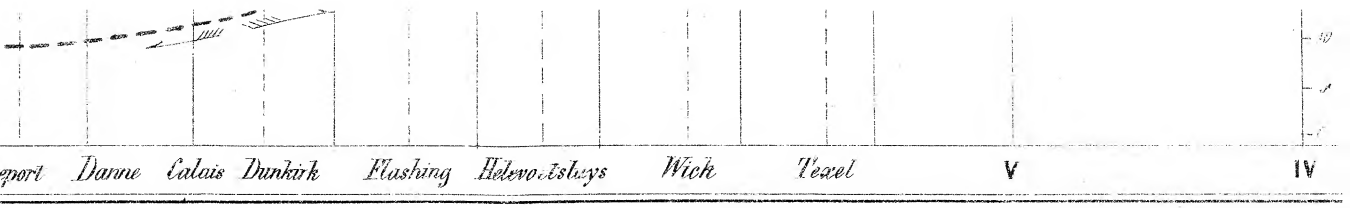
of the crest of the

Progress

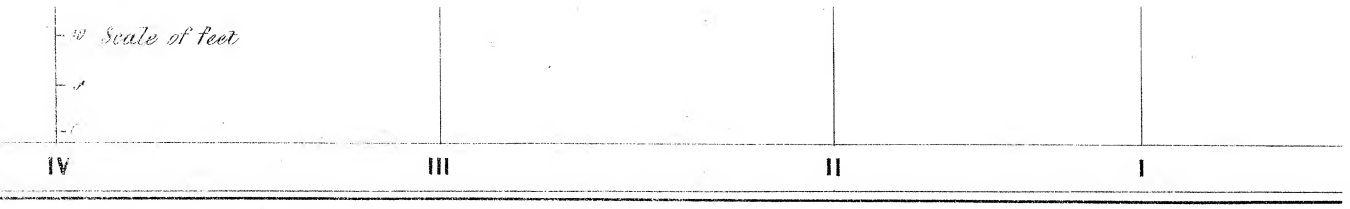
Scale of feet


XII
XI
12 feet.
Cromarty
Hour
XI
XII
I
III
IV

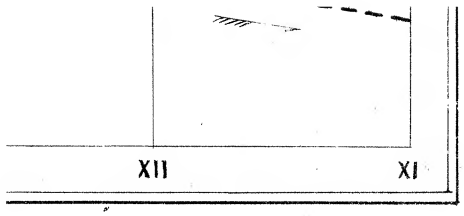

St. Mathews
Morlais
Heaux
Granville
C. Barfleur
Havre
Pt Ailly
Treport



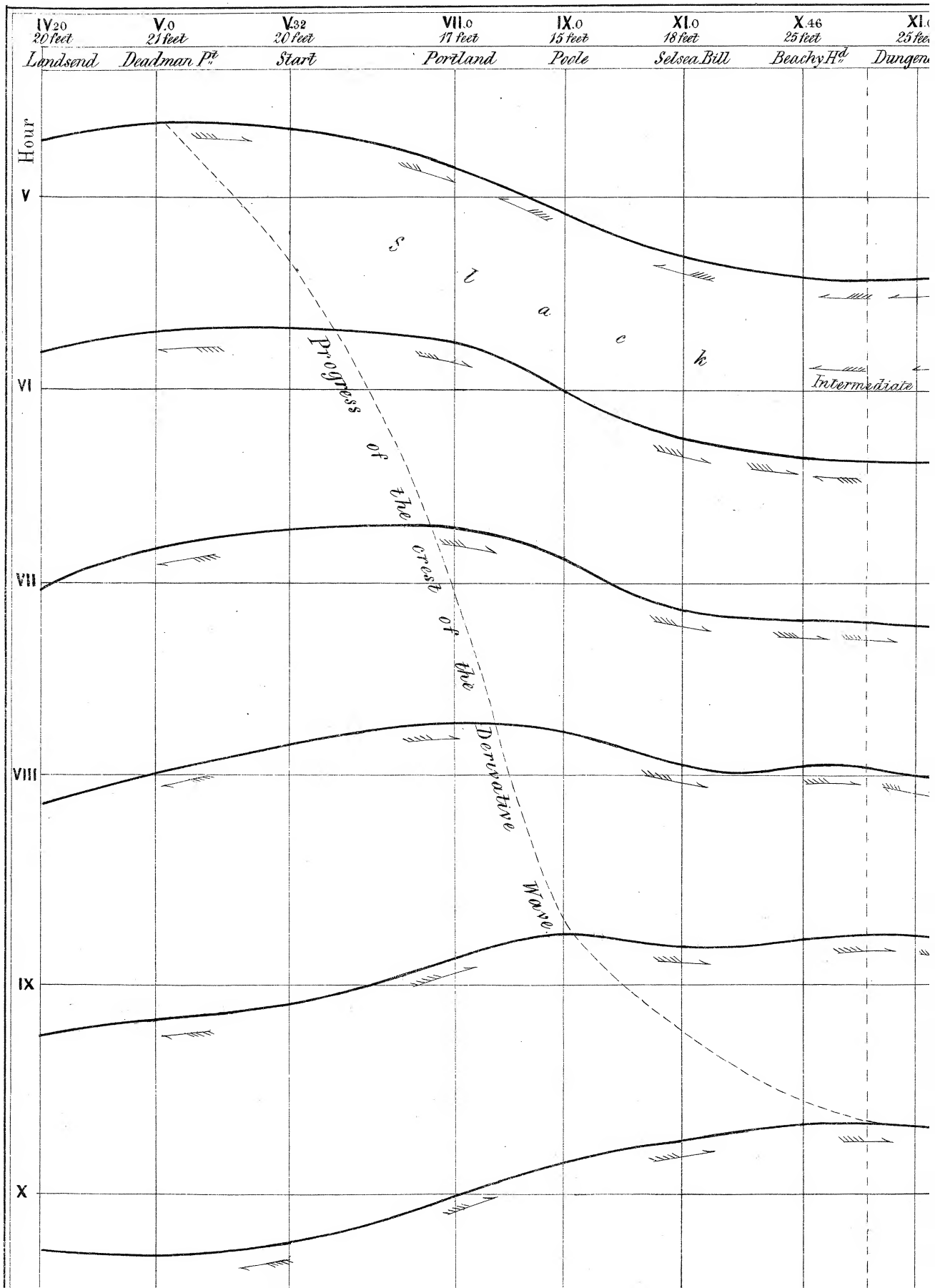
To accompany Cap.r Beechey's report upon the Tides of the English Channel.

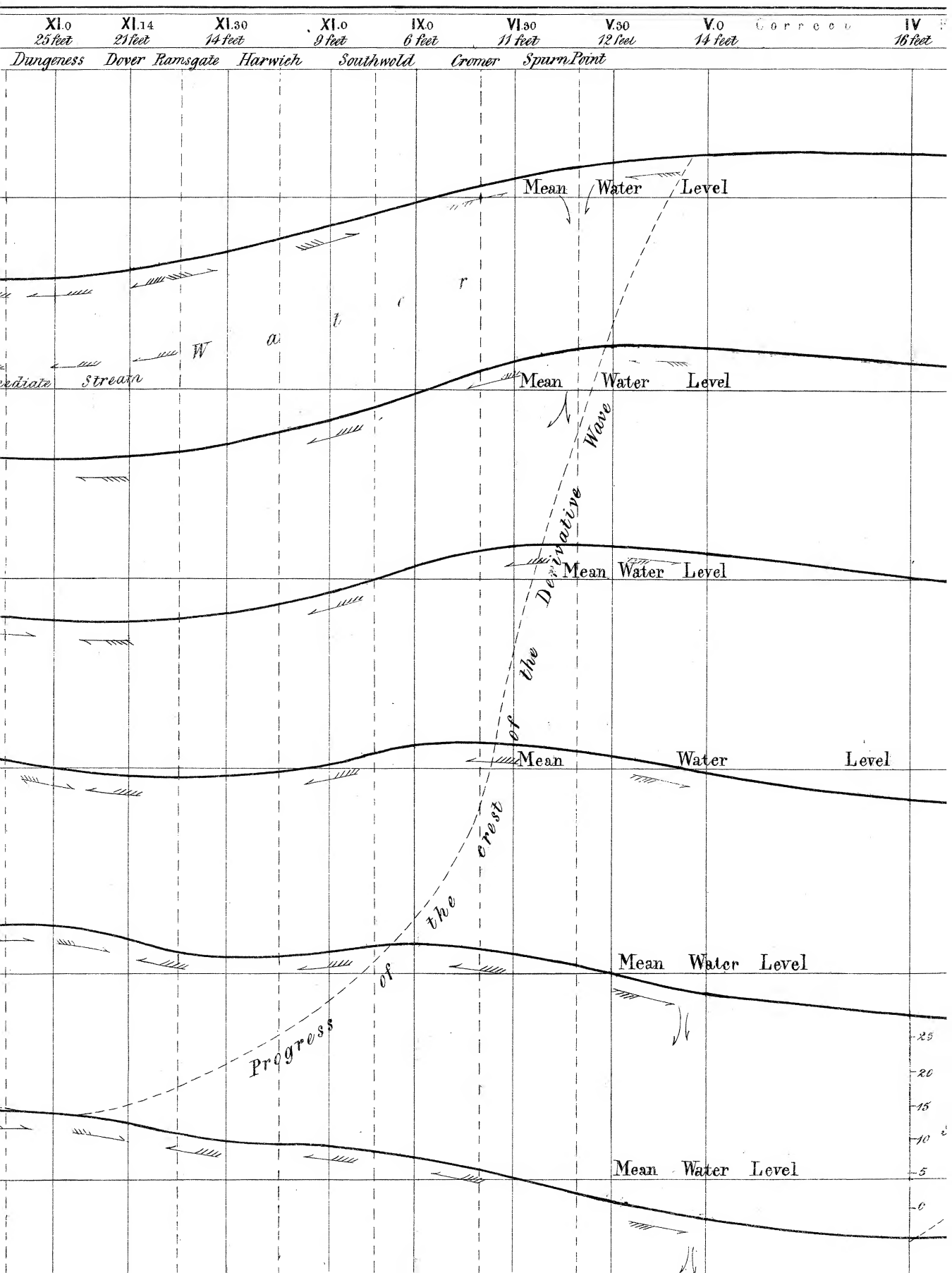


net.

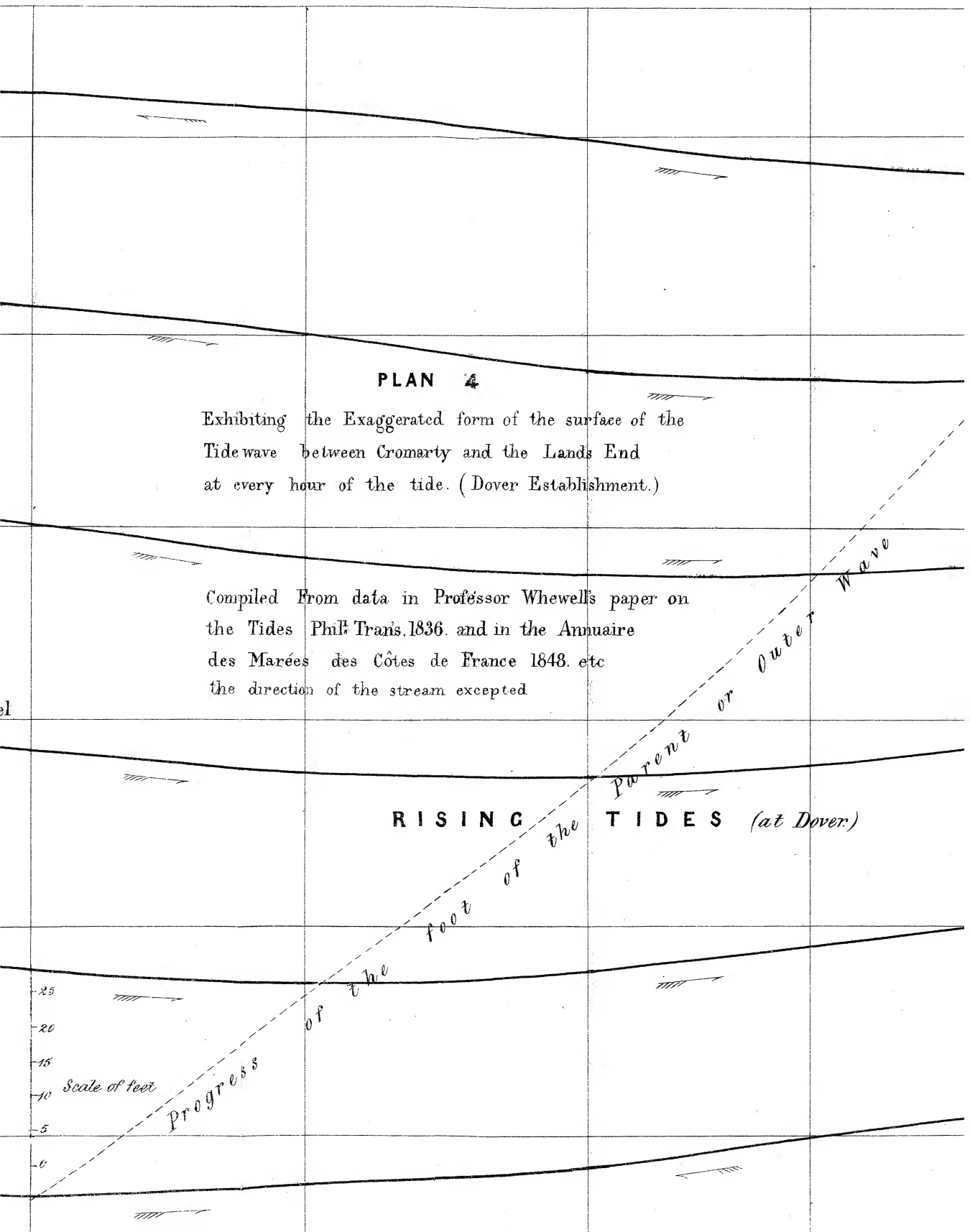


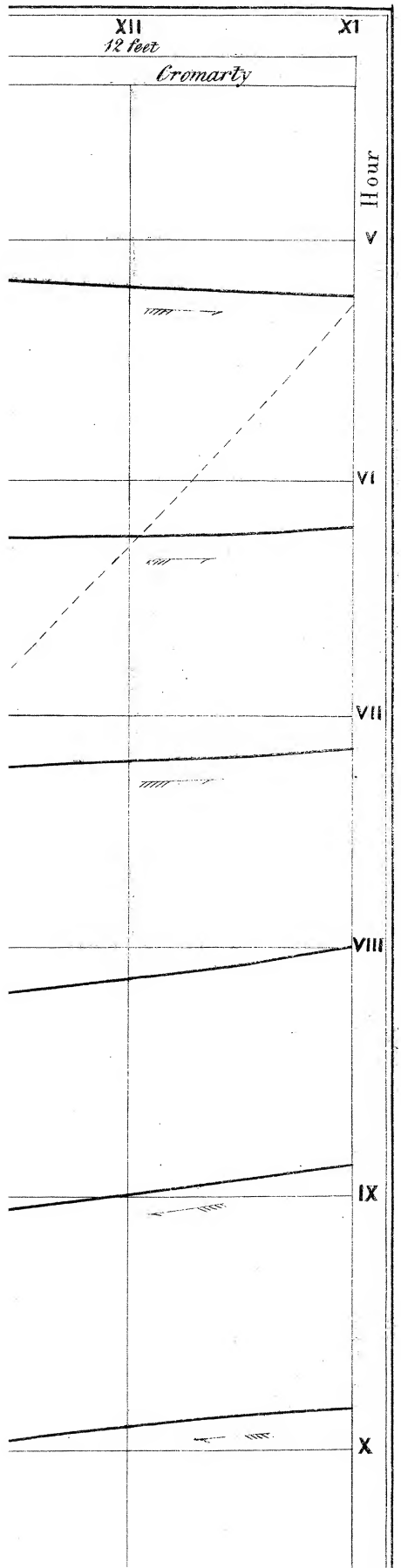
J. Basire, Litho.

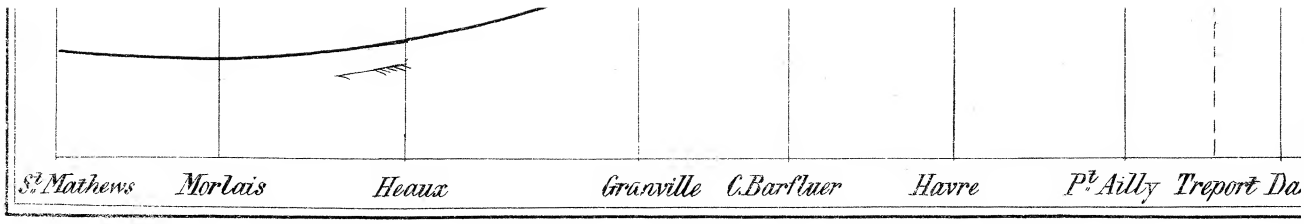

IV 20 feet
Landsend
V. 0 21 feet
Deadman Pt
V. 32 20 feet
Start
VII. 0 17 feet
Portland
IX. 0 15 feet
Poole
XI. 0 18 feet
Selsea Bill
X. 46 25 feet
Beachy Hd
XI. 25 fee
Dungen
Hour
V
VI
VII
VIII
IX
X
Slack
Intermediate
Progress of the crest of the Derivative Wave

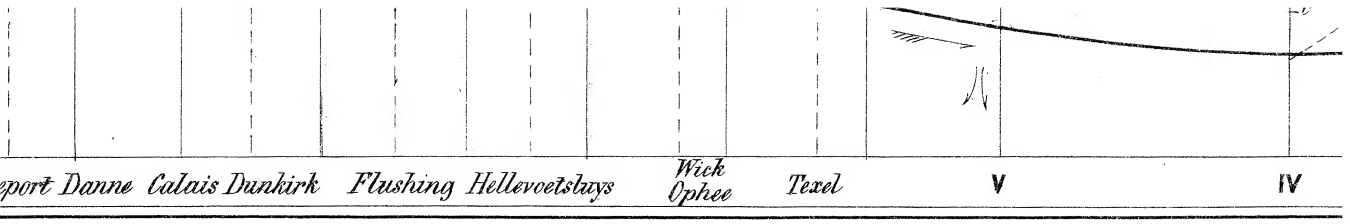

XI.0
25 feet
XI.14
21 feet
XI.30
14 feet
XI.0
9 feet
IX.0
6 feet
VI.30
11 feet
V.30
12 feet
V.0
14 feet
IV
16 feet
Dungeness
Dover
Ramsgate
Harwich
Southwold
Cromer
Spurn Point
Mean Water Level
Mean Water Level
Mean Water Level
Mean Water Level
Mean Water Level
Mean Water Level
Progress of the crest of the Derivative Wave
25
20
15
10
5
0

IV Establishment 16 feet | III 15 feet | Range | II 15 feet | I 13 feet

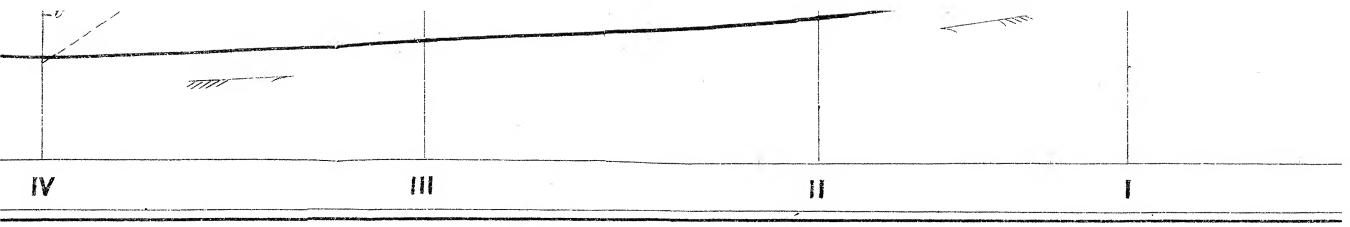



XII
12 feet
XI
Cromarty
Hour
V
VI
VII
VIII
IX
X


St. Mathews
Morlais
Heaux
Granville
C. Barfluer
Havre
Pt. Ailly
Treport
Da



To accompany Capt. Beechey's report upon the Tides of the English Channel



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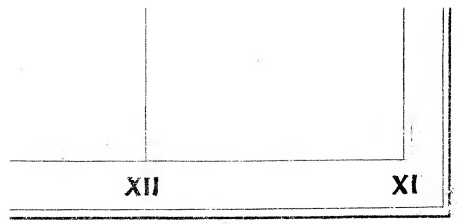


J.Bastire, Litho.

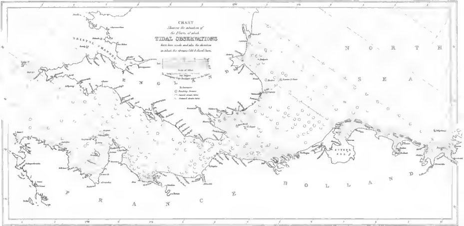


CHART
Shewing the situation of
the Places at which
TIDAL OBSERVATIONS
have been made and also the direction
in which the streams (ebb & flood) turn.
Scale of Miles
Reference
BRISTOL CHANNEL
E N G L A N D
N O R T H
S E A
H O L L A N D
F R A N C E
ZUYDER ZEE

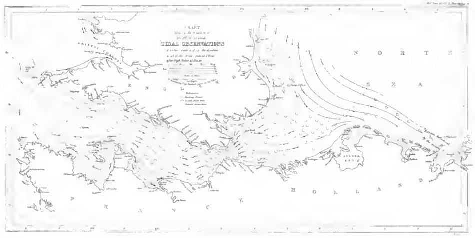


CHART
TIDAL OBSERVATIONS
after High Water at Dover
Scale of Miles
ENGLAND
NORTH SEA
FRANCE
HOLLAND
BRISTOL CHANNEL

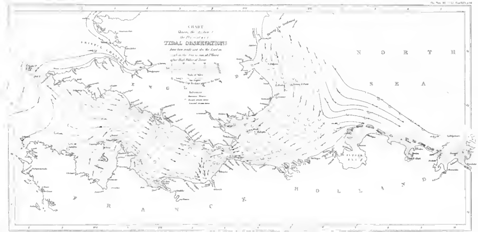
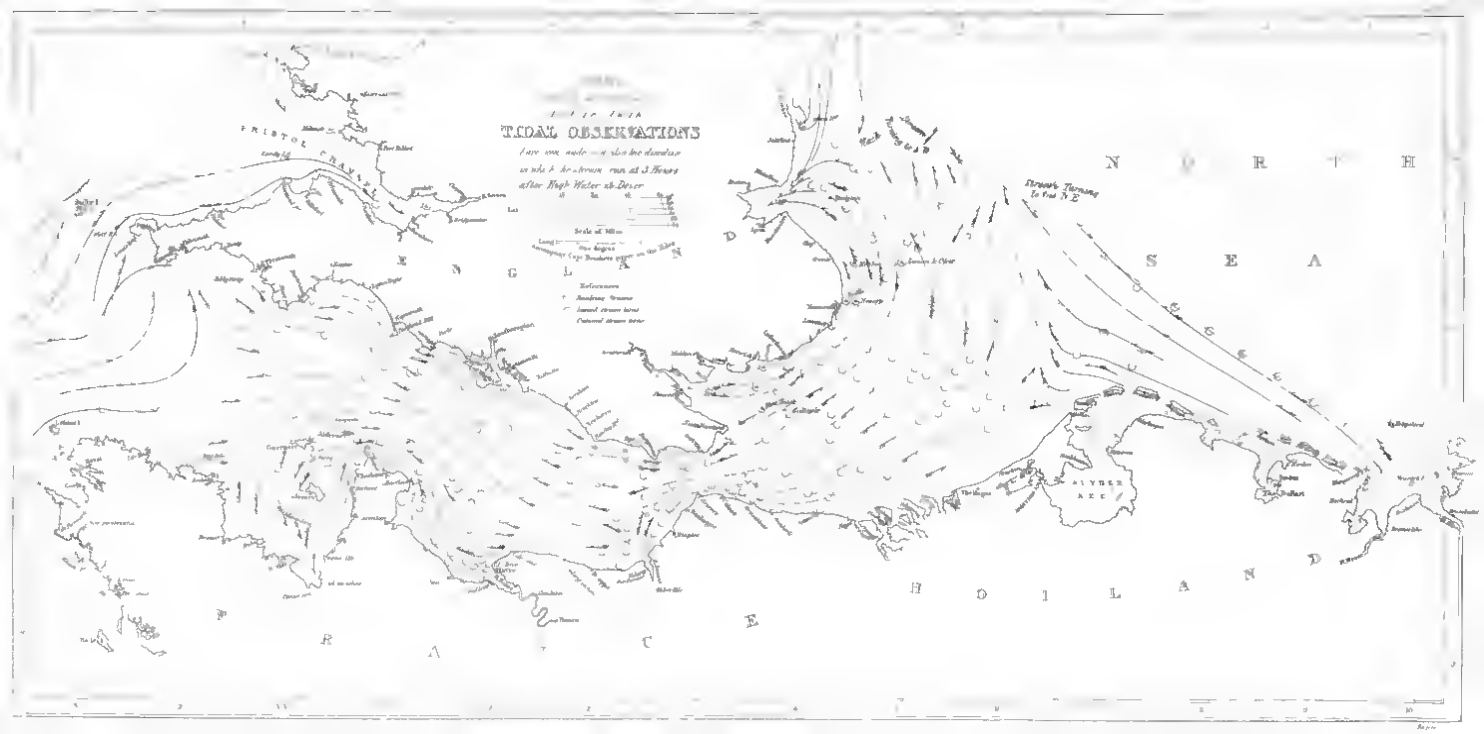


CHART
TIDAL OBSERVATIONS
after High Water at Dover
Reference
BRISTOL CHANNEL
N O R T H
S E A
H O L L A N D
F R A N C E


TIDAL OBSERVATIONS
Scale of Miles
Reference
Boundary Stream
Inward stream here
Outward stream here
BRISTOL CHANNEL
ENGLAND
FRANCE
NORTH SEA
HOLLAND
ALYDER ARC

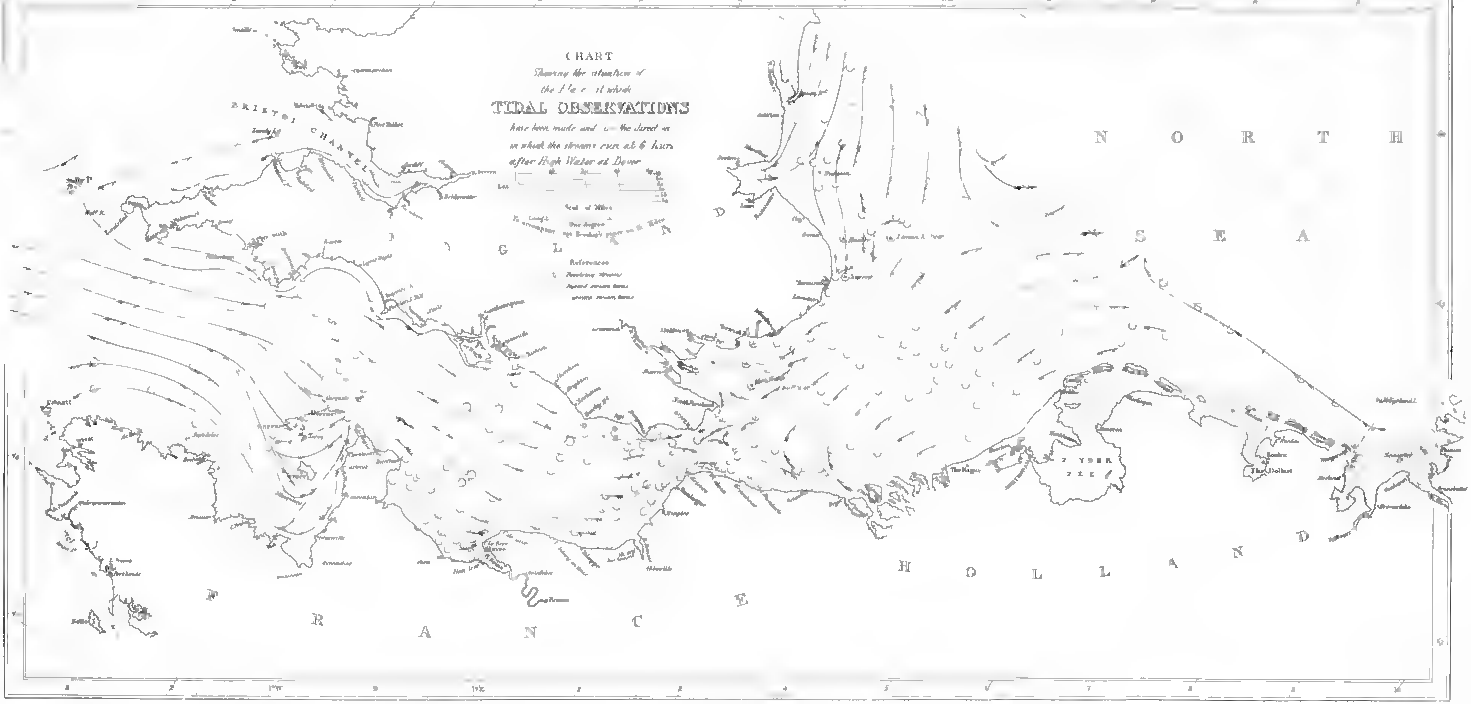
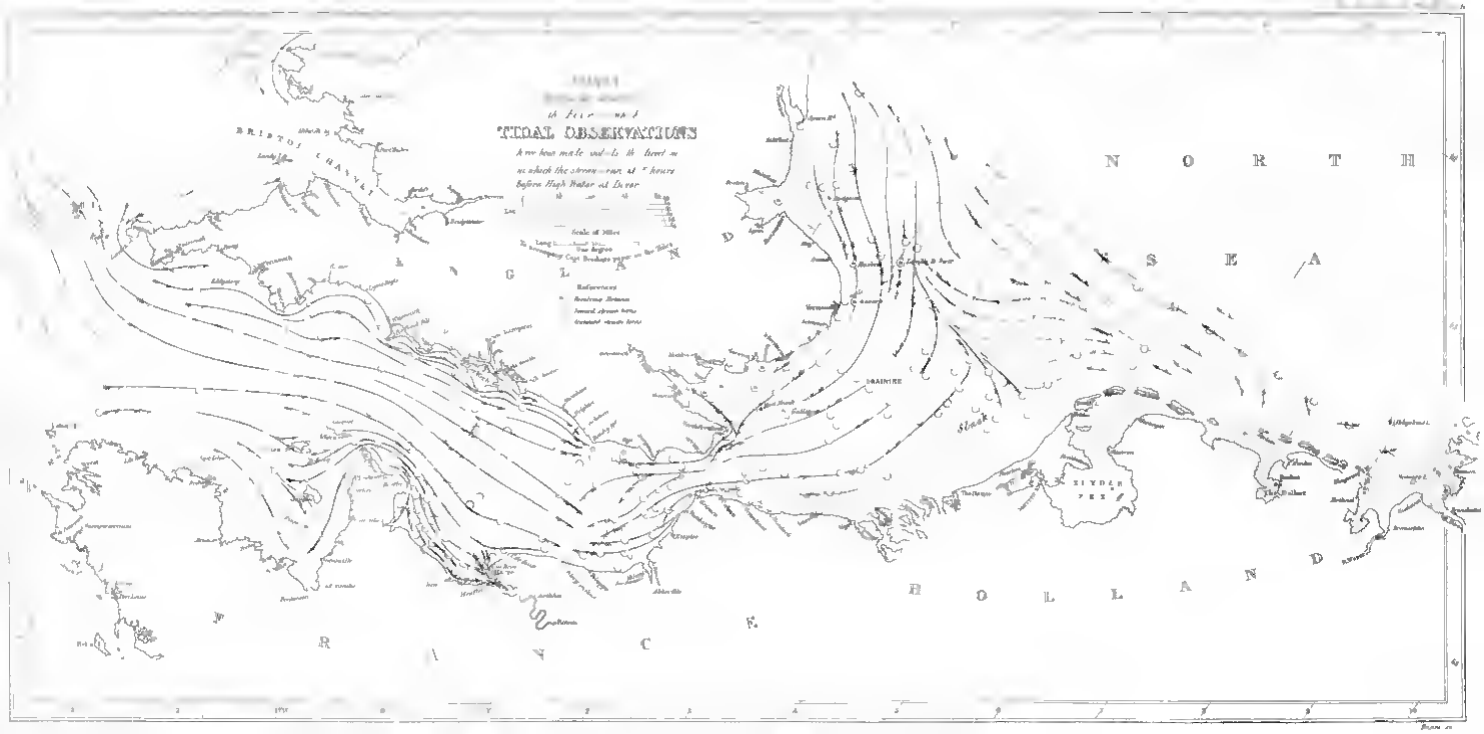


CHART
Shewing the situation of
the Place at which
TIDAL OBSERVATIONS
have been made and the direct ion
in which the stream runs at 6 hours
after High Water at Dover
References
BRISTOL CHANNEL
N O R T H
S E A
H O L L A N D
F R A N C E


TIDAL OBSERVATIONS
BRISTOL CHANNEL
ENGLAND
FRANCE
HOLLAND
NORTH SEA
ZUYDER ZEE

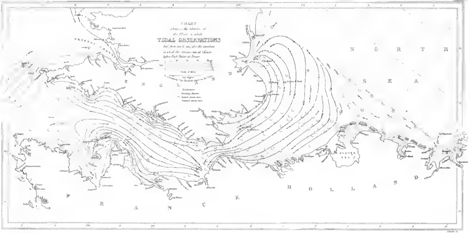


CHART
TIDAL OBSERVATIONS
NORTH SEA
ENGLAND
FRANCE
HOLLAND

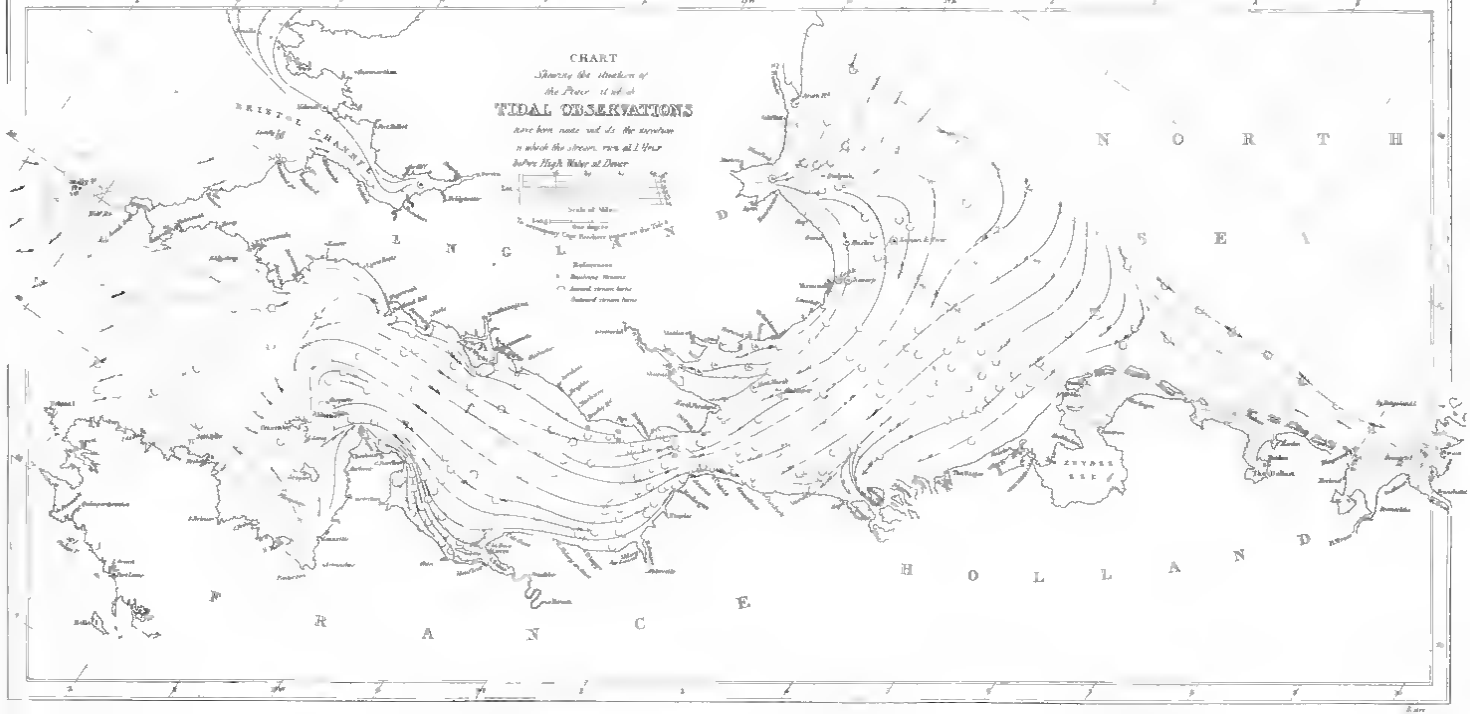


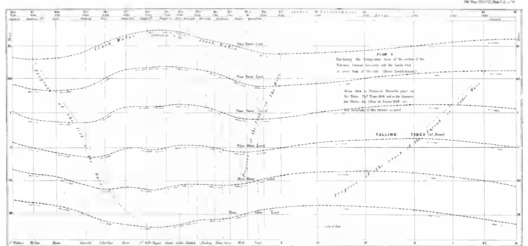
CHART
Shewing the direction of
the Flood & Ebb of
TIDAL OBSERVATIONS
were here made and the direction
in which the stream runs at 1 Hour
before High Water at Dover
Scale of Miles
Soundings
Stationary streams
Inward stream here
Outward stream here
BRISTOL CHANNEL
ENGLAND
NORTH SEA
HOLLAND
ZUYDER ZEE
FRANCE

PLAN 2

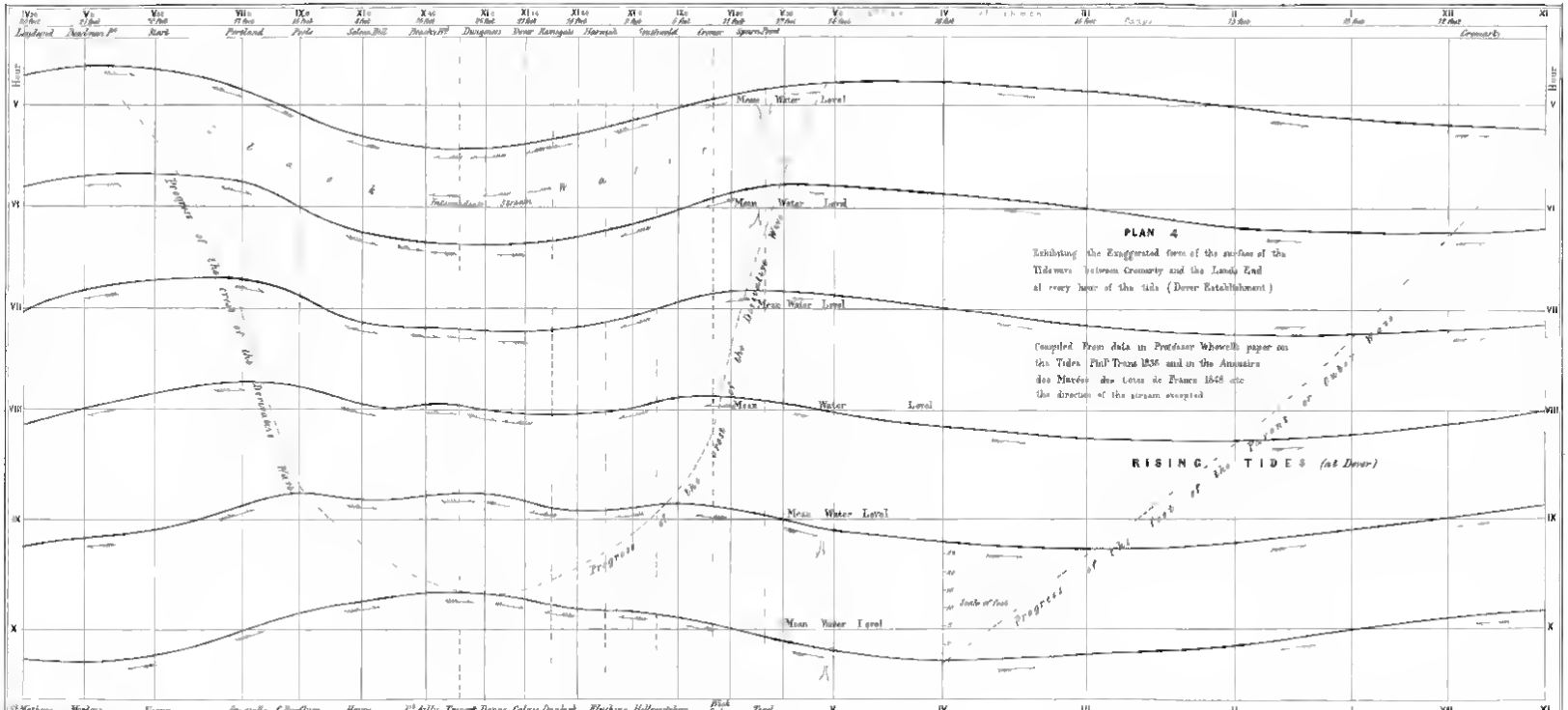
the direction o
Sets at the Tide

RISING TIDES AT DOVER

These accounts are the mean of the Wave Lines
as they are drawn upon the English and French Coasts



To accompany Capt. Beechey's report upon the Tides of the ... Channel



To accompany Capt Beaufort's report upon the Tides of the English Channel

J Reeve lithe